HOW CLEAN IS SAFE?

UNCLASSIFIED

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EXECUTIVE SUMMARY

This report was prepared for the Air Force National Security Policy Division (AF/XONP), which is responsible for counter-chemical, biological, and nuclear policy strategy and concept development.

Problem

The United States Air Force (USAF) possesses some limited capabilities to decontaminate equipment, personnel, casualties and aircraft. Current policies, though, do not specify the levels to which chemical warfare agents must be removed from aircraft and equipment. The increased threat of chemical warfare heightens the need for an Air Force policy on the certification of contaminated equipment, aircraft, and casualties returning from a forward area. This decontamination policy must encompass both a set of cleanliness standards that specify safe concentrations of chemical agents and a description of how the Air Force will use these standards.

Report Purpose and Approach

This report provides AF/XONP with a view of the past and current efforts concerning the question of how clean is safe enough to protect the different populations of concern for the Air Force policy on the certification of chemically contaminated casualties, equipment, and aircraft returning from a forward area. It then recommends cleanliness standards and a decontamination policy and suggests an implementation timeline.

The results of this study came from a six month investigation of the past, current, and future studies to determine harmful levels of chemical warfare agents; the technical capabilities for detection and decontamination; the regulatory agency decontamination or toxicity level policies; and the issues of concern for the Air Force. Individuals consulted in this assessment include personnel from a mix of government agencies, industry, and education, including: AF/XONP, U.S. Transportation Command, Air Mobility Command, Science Applications International Corporation, U.S. Army Aeromedical Center, and Massachusetts Institute of Technology Lincoln Laboratories. These individuals provided valuable perspectives on the available toxicity data, the detection and decontamination capabilities, the regulatory agencies' stances, the problems specific to the Civil Reserve Air Fleet, and the specific issues of concern for the Air Force. From these issues of concern emerged six criteria upon which to develop any Air Force decontamination policy. This report then developed a decontamination policy and implementation timeline to fulfill the criteria.

Recommendations

The Air Force should:

(1) Apply six criteria to any decontamination policy

These criteria (as described further in this report) in their applicable orders are:

1. Prevent health risks to humans
2. Prevent the spread of contamination at returning bases/locations
3. Minimize mission impact
4. Be politically feasible
5. Be technologically feasible
6. Minimize costs

(2) Develop cleanliness standards independent of detection capabilities

The DOD interim standard, "if you cannot detect it, it is not there," is not sufficient to protect humans from harmful effects. The levels at which chemical agents are harmful to humans are independent of detection and decontamination capabilities. Thus, the cleanliness standards should be set according to the levels necessary to prevent harm to humans and to prevent the spread of contamination. If the available detection or decontamination equipment is not capable of certifying the casualties, equipment, or aircraft to the necessary level, then the Air Force must adhere to the necessary precautions to prevent health risks or the spread of contamination.

(3) *Follow the Army's guidelines for handling contaminated casualties*

These guidelines have been accepted throughout DOD. They also fulfill the six criteria for a decontamination policy recommended by this report.

(4) Develop a decontamination policy with three certification levels for decontaminated aircraft and equipment

To satisfy the previously mentioned criteria, the Air Force should consider three separate populations for protection: *workers/military personnel in protective gear*, *workers/military personnel without protective gear*, and the *general population*. These populations should correspond with cleanliness levels similar to the Army's levels for its chemical agents and munitions destruction facilities. These levels are defined as Levels 1X, 3X, and 5X:

- **Level 1X**: Contaminated objects that have not yet been decontaminated or obects that still contain detectable agent levels at or above the permissible levels for workers/military personnel without protective gear. Only *workers/military personnel in protective gear* should be allowed to use these objects.

- **Level 3X**: Potentially contaminated objects or previously contaminated objects that have been decontaminated to show concentrations below the permissible levels for workers/military personnel without protective gear. *Workers/military personnel without protective gear* should be allowed to use these objects under normal working conditions (not to include performing maintenance).

- **Level 5X:** Fully decontaminated objects that show concentrations below the permissible levels for the general population. Level 5X materials must have undergone heat treatment of at least 1000° for at least 15 minutes or a similar process that insures the destruction of any residual agent that may be inaccessible to chemical treatment in cracks or crevices. The *general population* should be allowed to use these objects.

The permissible levels referred to in the above definitions should be defined according to the Army's Permissible Agent Hazard Concentrations in Air used in its chemical agents and munitions destruction facilities until the low-level effects study is finalized in FY04.

Next, the Air Force must define the allowable uses for aircraft and equipment certified at each level. These definitions must include the populations that should be allowed to operate, occupy, or use the equipment or aircraft, the risks of spreading contamination to other equipment or airfields, the necessary precautions to prevent this spread, and any special considerations for each certification level.

(5) Seek regulatory agency approval

The Air Force should first seek approval of its decontamination policy from the National Institute for Occupational Safety and Health and the Environmental Protection Agency. Once the Air Force gains this approval, it should make an agreement with the Federal Aviation Administration concerning the landing of certified aircraft on commercial or military airstrips and concerning the safe return of Civil Reserve Air Fleet aircraft to commercial service.

(6) Seek individual agreements with allied countries

Some contaminated aircraft may need to land in allied countries on the way back to the US from a forward-deployed area. The U.S. Air Force must not wait for international acceptance of the decontamination policy, but must actively seek agreements with critical allied countries (those countries with whom cooperation will most likely be needed).

(7) Use an adjusted version of Air Mobility Command's (AMC) schedule for standard/policy implementation

Table 1. Implementation Timeline

Year	Action/Event
FY01	AMC should have reviewed and amended the DOD interim cleanliness standard to be independent of detection technology.
FY03	AMC should have converted the DOD standard into a national standard. The Air Force should be seeking individual agreements with critical allied countries.
FY04	The low-level exposure effects study will be finalized.
FY05	AMC should review and amend the DOD/National standard in light of the low level exposure study.
FY08	The amended standard should be internationally accepted.

(8) Use laboratory analytical techniques to certify aircraft and equipment for use by the general population

Currently, battlefield detectors are only capable of certifying aircraft and equipment for use by workers/military personnel with and without protective gear. The Air Force should seek to improve these detectors, but until they have the capability to certify for general population safety, laboratory analytical techniques must be used for this purpose.

(9) Continually evaluate the feasibility of alternate decontamination technologies

The Air Force should determine the effects that the Canadian Aqueous System for Chemical-Biological Agent Decontamination (CASCAD) has on sensitive aircraft materials for the possible replacement of DS-2, water and detergent solution, and the C-8 Direct Application Decontamination System (DADS). CASCAD is more effective than these other systems and it has neither toxic residues nor corrosive effects. The Air Force should also evaluate low temperature decontamination, CW resistant coatings, Decon Foam 100, and the Atmospheric Pressure Plasma Jet (APPJ) as they become available.

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1. INTRODUCTION

1.1 Problem Context[1]

The Air Force acts as the single manager for airlift requirements for all of the military services. All U.S. forces are originally projected from the continental United States. Most of these forces traverse allied countries while en route to overseas locations.

There is an increasing threat of the use of chemical warfare (CW) agents to disrupt U.S. force projection by rendering equipment or aircraft unusable.[2] Such a disruption could impose safety risks, financial burdens, and mission disruption upon the Air Force. In order to preempt these aftermath effects, the Air Force must create a policy on the level of decontamination necessary to certify the safety of equipment, personnel, casualties, and aircraft to return to normal peacetime operations. This problem lends itself to analysis in three contexts: technical, political (both international and domestic), and mission impact contexts. The latter part of this introduction addresses each of these contexts.

1.2 Report Purpose and Structure

This report is intended to help the Air Force develop a decontamination policy and identify areas for further research. The decontamination policy must contain cleanliness standards that will both prevent health risks and prevent the spread of contamination. Thus, this report addresses both the cleanliness standards and the larger decontamination policy.

In order to accomplish this purpose, this report first identifies the characteristics of chemical warfare agents and their effects on humans, aircraft, and equipment. It then identifies the levels at which these chemical warfare agents are harmful; examines the decontamination methods available to rid casualties, aircraft, and equipment of these agents; and examines the detection technology available to certify that the objects have been decontaminated to safe levels. Once the cleanliness standards have been developed, this report looks to other military decontamination-related policies and regulatory agency concerns to provide guidance for an Air Force decontamination policy to define the allowable uses for certified casualties, aircraft, and equipment. It then identifies the issues central to the Air Force in light of the other military policies and regulatory agency concerns, developing criteria with which to evaluate any

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[1] Lieutenant Colonel Marcy Atwood, Then Branch Chief, Concepts and Strategy, National Security Policy Division, Dir for Nuclear and Counterproliferation, DCS/Air and Space Operations. Now AF/CCX. Field Work Description Document. October 1999.

[2] Contamination from CW agents could occur in the continental U.S., at allied installations, and/or at forward operating locations.

Air Force decontamination policy. Finally, this report recommends a decontamination policy that meets these criteria.

1.3 Background Information

The three facets of the problem context will now be explored in more depth. This section will also depict the organizational context in which this problem lies and will explain the Air Force's current plan for developing a decontamination policy.

1.3.1 PROBLEM CONTEXT

The *technical* concerns include concerns about toxicity data and detection and decontamination equipment and capabilities. CW agents affect not only humans, but also affect aircraft and equipment. The Air Force must determine how to use the available toxicity data and technology (both detection and decontamination) to protect humans, aircraft, and equipment. It must also recognize where it needs to expend research efforts to better the data.

The *political* context includes both domestic and international concerns.

Domestic: When Air Force personnel, casualties, aircraft, and equipment return from a contaminated forward-deployed area, the Air Force will resume normal operations. In order to prepare the contaminated entities to resume these operations the Air Force must be aware of the interests, concerns, and policies of U.S. regulatory organizations. These organizations will be concerned with:

- The exposure of Air Force personnel to hazardous chemical levels during everyday activities
- The transportation of civilians and civilian equipment by the Air Force
- The return of previously contaminated Civil Reserve Air Fleet (CRAF) aircraft to commercial operations
- The disposal of contaminated equipment
- The disposal of decontamination remains
- The treatment or disposal of casualties

International: When returning to the US, aircraft may need to transit, land in, and/or decontaminate in allied countries. The Air Force must ensure that its equipment and aircraft will not contaminate anything in these countries. It must also be concerned with the possibility of allied countries denying landing, transiting, or decontaminating rights to the United States Air Force (USAF).

In light of the *mission* context, the USAF must first be concerned with transporting its personnel, casualties, aircraft, and equipment back to the United States if this transport is essential to fulfilling Air Force mission requirements. The Air Force must compare the available options and their impact on resuming the USAF mission in non-deployment situations. For example, the Air Force must decide if it should decontaminate at the forward-deployed area or back in the US. If the aircraft or equipment cannot be decontaminated sufficiently, the Air Force must decide if it will return them to the US or dispose of

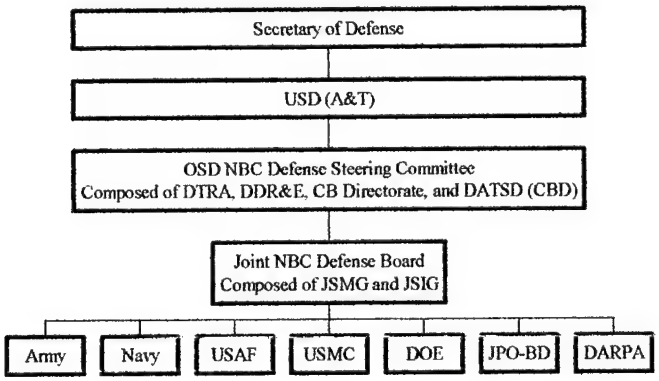
them in the forward-deployed area. The Air Force must also decide if the mission essential operations can be carried out in protective gear.

Then, upon return to the US, the Air Force needs to ensure that the returning installation will not become contaminated. The USAF must then be concerned with carrying out its missions once all personnel, casualties, aircraft, and equipment have been returned to the US. The Air Force not only transports military equipment and personnel to and from military installations, but in some cases it also transports civilian equipment and civilians to and from military and civilian installations. It must be able to do this without harming or contaminating any of the equipment and people that are transported. The Air Force must also be concerned about the health risks to those people performing maintenance on the equipment or aircraft.

The Air Force must ensure that the chemical agents and/or decontamination methods do not render the equipment or aircraft unusable. The decontamination process must also not contaminate the environment. If the contaminated equipment or aircraft must be disposed of, the Air Force must provide proper disposal without contaminating the environment or creating any potentially hazardous situations for humans. The Air Force must compare the costs and mission impact of decontaminating to the costs and mission impact of disposing of the affected equipment or aircraft.

1.3.2 ORGANIZATIONAL CONTEXT[3]

Department of Defense Chemical and Biological Defense Program



The DOD Chemical and Biological Defense Program (CBDP) coordinates and oversees the joint efforts on chemical and biological warfare issues. The Air Force is specifically in charge of decontamination issues. The Army serves as the Executive Agent for the Joint Service Nuclear, Biological, and Chemical Defense Board. This board seeks to coordinate and integrate research and

[3] DOD Chemical and Biological Defense Program Organization. http://www.dtra.mil/chem/org.html. 1/6/00.

development, testing and evaluation, and acquisition requirements for the CBDP. The CBDP's strategy to address low-level chemical agent focuses on chemical warfare agent hazard identification. The CBDP attempts to integrate key stakeholders by compiling research data into technical references that can be used for doctrine and policy development. Specific oversight responsibilities belong to the Joint Service Material Group (JSMG) and the Joint Service Integration Group (JSIG). JSMG oversees monitoring and detection development issues, while the JSIG oversees the related operational application requirement issues. In order to provide consistent policies, other stakeholders[4] in DOD that are not necessarily in the Chemical and Biological Defense community must also be integrated into the process.[5]

1.3.3 CURRENT PLAN FOR AIR FORCE DECONTAMINATION POLICY [6]

Although the Air Force is responsible for decontamination issues, it does not have cleanliness standards or an overarching decontamination policy. Within the Air Force, though, Air Mobility Command (AMC) and Transportation Command (TRANSCOM) have a plan to create a decontamination policy.

There are three reasons for the current lack of cleanliness standards. First, AMC believes that the best decontamination method for aircraft is aeration for the exterior and heat treatment for the interior. Second, current detection capabilities are not sensitive enough to support a certification program. Finally, uncertainty exists concerning which countries will allow transit through their country or cleaning in their country.

AMC and TRANSCOM's proposed timeline for the development of a cleanliness standard follows:

FY04 The study on the effects of low level exposure will be completed.
FY05 AMC will review and amend the established DOD interim standard.
FY08 AMC will have converted the DOD standard into a national standard.
FY12 This standard will be internationally accepted.

To speed this process, AMC proposes to increase awareness by addressing the decontamination issue at the Weapons of Mass Destruction Preparedness Group, in Congressional testimony, at the Counterproliferation Council, and in other senior forums. It will also attempt to accelerate the Chemical Cleanliness timelines by revisiting the JSIG Study timelines. In order to provide a cooperative

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[4] These stakeholders include, but are not limited to the Army Medical Command NBC-Environmental (NBC-E); Marine Corps Combat Development Command; Medical Resources; Plans and Policy for Naval Operations; U.S. Special Operations Command; Air Force Office of the Surgeon General; Assistant Secretary of Defense (ASD) for Health Affairs; Service Surgeons General; CINC surgeons; JTF surgeons; Joint Environmental Surveillance Working Group (JESWG); Joint Preventive Medicine Policy Group; and the Research Working Group of the Military and Veterans Health Coordinating Board.

[5] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 28-29.

[6] All information in Section 1.3.3 came from an e-mail from David Grube and Lt Col Jimmie Jacobs of AMC on 12/3/99.

environment for expediting this process, AMC has begun to work with other governmental agencies. AMC also notes that the same amount of effort needs to be focused towards establishing a biological standard.

Other efforts to create a certification standard are also underway. For example, AMC's Readiness Working Group tasked AMC Logistics Group to examine the feasibility of a certification program. Decontamination systems and detection technologies, such as the German decontamination system and the Joint Chemical Agent Detector (to be fielded in FY02), are also being developed for sensitive equipment and aircraft. In light of these current efforts, this report will now delve into the first issue of interest, the characteristics and harmful effects of chemical warfare agents.

2. CHARACTERISTICS AND HARMFUL EFFECTS OF CHEMICAL WARFARE AGENTS

When deciding how "clean is safe" for the Air Force's purposes, one must first explore the characteristics and effects of chemical warfare agents. Chemical warfare (CW) agents have harmful effects on humans, aircraft, and equipment. These effects depend on the specific agent's characteristics. The chemical agent characteristics and effects are discussed below.

2.1 Chemical Warfare Agent Characteristics[7]

Chemical warfare agents are classified according to lethality, mode of action, speed of action, toxicity, persistency, and state. Short descriptions of these characteristics follow:

Lethality classifies CW agents as lethal or non-lethal. Those agents designed to be lethal are intended to cause fatalities under battlefield conditions. Sub-lethal doses of these agents may cause incapacitation. Non-lethal agents can kill in large doses, but were originally designed only to cause incapacitation or injury.

Mode of action indicates how the CW agent affects living organisms. This report considers inhalation and percutaneous routes of exposure. Agents that act via inhalation can cause damage immediately as they enter the lungs. The rapidly enter the bloodstream where they can cause more damage after they are breathed in. Agents that act percutaneously enter the body through the skin, eyes, or mucous membranes and may damage these tissues upon entry.

Persistency measures the length of time that an agent remains a hazard. Non-persistent agents tend to be rather volatile and evaporate quickly, dissipating within a few minutes to about one hour. Semi-persistent agents usually linger for several hours to one day. Persistent agents tend to be relatively thick and oily. They can last for several days to a few weeks. CW agents can be thickened to increase persistency by adding viscous materials. The actual length of time that an agent remains a hazard varies significantly depending on the environment (soil, vegetation, material of contact, etc.) and meteorological conditions (temperature, wind speed, atmospheric stability, moisture, and sunlight). CW agents dissipate more rapidly when exposed to high wind speeds, high temperatures, and an unstable atmosphere.

Speed of action measures the time between exposure to the agent and onset of the agent's effects. Rapid-acting agents cause symptoms to appear almost instantaneously and may cause fatalities in a few minutes. Slow-acting agents can take days before causing the first symptoms and weeks or months before causing fatalities. Generally, the speed of action increases at higher doses of the same agent.

State identifies the agent's physical form. CW agents can be solids, liquids, or gases, but most are liquids. Nerve gas, mustard gas, and poison gas are actually liquids. They are called "gases" because they are disseminated as aerosols or vapor clouds that act like gases.

Toxicity measures the quantity of a substance required to achieve a given effect. CW agents are highly toxic compounds that work via inhalation or skin contact.

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[7] *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper, U.S. Central Intelligence Agency, 1998. p. 23-26.

The next section will apply these characteristics to the different types of chemical agents and will explain the agents' effects on humans.

2.2 CW Agent Types and Effects on Humans[8]

Chemical agent types include choking agents, blood agents, blister agents, G-series nerve agents, V-series nerve agents, tear gas agents, vomiting agents, and psychochemicals.

Choking agents corrode the respiratory system and result in pulmonary edema. The victim's lungs fill with fluid, choking the victim. These agents are heavy gases and remain near ground level when dispersed. They are non-persistent, causing them to dissipate rapidly in a breeze. Choking agents include chlorine and phosgene.

Blood agents are absorbed primarily by inhalation. They prevent the victim's cells from using oxygen normally and they cause rapid damage to body tissues. They are highly volatile and dissipate rapidly when in their gaseous state. Blood agents rapidly degrade a mask filter's effectiveness. They can be combined with other agents to defeat the protective capabilities of masks. Blood agents include hydrogen cyanide (AC) and cyanogen chloride (CK).

Blister (vesicant) agents are used with the intention of causing medical casualties, restricting the use of terrain, slowing movements, or impeding the use of material and installations. They affect the eyes and lungs and blister the skin. Most of these agents cause little or no pain at the time of exposure, except for lewisite, which causes pain on contact. Blister agents include sulfur mustard, nitrogen mustard, and lewisite.

Sulfur mustard requires additional attention because it is considered to be the ideal CW agent. It presents hazards both respiratorily and percutaneously. It is persistent and presents a long-term hazard. It causes long-term and debilitating injuries. The persistency of sulfur mustard is limited under humid conditions.

Lewisite hydrolyzes rapidly when exposed to atmospheric moisture. This hydrolyzation causes it to form a nonvolatile solid which lowers the vapor hazard from contaminated materials and decreases the penetration of the agent through and into materials and clothing. Lewisite is less persistent than sulfur mustard and its persistency is limited under humid conditions.

G-Series Nerve Agents are more lethal and have a speed of action faster than that of mustard. They inhibiting the action of the enzyme acetylcholinesterase, causing nervous impulses to continue to be transmitted. They act within seconds of exposure and can be absorbed both percutaneously or through the respiratory tract. Some of these agents, however, like tabun (GA) and sarin (GB) tend to be relatively non-persistent and present less of a percutaneous hazard than a vapor hazard. These agents can cause paralysis of the respiratory muscles and convulsive spasms that will eventually suffocate the victim to death.[9] The lethal exposure dose can cause death in minutes. Even non-lethal dose exposures to nerve agents can cause permanent neurological damage.[10] Persistent G-series nerve agents including, GF and GD, present more of a percutaneous hazard. GD can remain in an area for periods of longer than one day,

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[8] Except where otherwise noted, this section was taken from: *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper, U.S. Central Intelligence Agency, 1998. p.26-28.

[9] Tabun Fact Sheet. CW Agents Source References. Http://projects.sipri.se/cbw/cbw-agents/tabun.html. 3/26/00.

[10] Tabun Fact Sheet.

depending on the atmospheric conditions.[11] G-Series Nerve Agents include GA, GB, soman (GD), and GF.

V-Series nerve agents are similar to but more advanced than G-Series agents. They are more toxic and more persistent than G-agents. They present a greater percutaneous hazard and cause long-term contamination of territory and equipment. V-Series nerve agents include VE, VG, VM, VS, and VX.

Tear gas agents (riot control agents) are not considered by the U.S. Government to be CW agents because they are non-lethal in all but the highest concentrations, therefore they will not be considered in this report.

Vomiting agents are also considered to be riot control agents because they usually only cause discomfort, therefore they will not be considered in this report.

Psychochemicals including lysergic acid diethylamide (LSD), 3-quinuclidinyl benzilate (BZ), and benactyzine will not be considered in this report.

2.3 Harmful Effects on Aircraft and Equipment

Not only are chemical warfare agents harmful to humans, but they may also cause the corrosion of aircraft materials and structures, the swelling and degradation of seals, insulation, and transparencies, and the deterioration of avionics components and wiring.[12] Unfortunately, the effects of some decontamination substances and procedures may also be severe.

This report assumes that a level of chemical agent that is not harmful to humans will not be harmful to materials (a human cleanliness standard is more strict than a no-material-degradation standard). It assumes that those areas of an aircraft or equipment that will be exposed to humans will need to be cleaned according to the level that will be harmful to humans. The basis of this assumption is that equipment that requires a human interface is no longer useful if it cannot be used by humans. It also assumes that there are no areas of an aircraft or equipment that will never have to come into contact with humans at least for maintenance needs. Thus, aircraft and equipment will always be subjected to the cleanliness standard necessary to protect humans.

It may be possible for a chemical agent to be absorbed into a material or electronic equipment in such a manner that it does not present a percutaneous or vapor threat to humans, but may damage the equipment or material. This effect is not addressed in this report due to the small chance that these effects will take priority over the effects on humans when returning aircraft and equipment back to the US. It is more likely to be addressed in a war-time operational context where the Air Force may continue to operate in a contaminated environment. The effects that chemical agents have on aircraft and equipment

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[11] Soman Fact Sheet. CW Agents Source References. Http://projects.sipri.se/cbw/cbw-agents/tabun.html. 3/26/00.
[12] Byrd, Norman R. (Inventor). Chemical Resistant Coatings. United States Patent: 5,858,468. McDonnell Douglas Corporation, St. Louis, MO. p.3.

are therefore only important in the context addressed by this report in deciding how long to wait before decontaminating the aircraft or equipment after it has come into contact with a CW agent.

3. CW AGENT LEVELS HARMFUL TO HUMANS

Once the characteristics, types, and effects of chemical agents have been identified, one must identify the concentrations of the chemical agents necessary to cause these harmful effects in humans. The concentrations that cause harmful effects are very different from the lethal concentrations, which cause death (See Appendix D for lethal doses). Uncertainties exist in much of the data on the levels at which CW agents are harmful to humans. Despite these uncertainties, many efforts have been made, and continue to be made to determine these levels. This section states the existing uncertainties, proposes population groups of concern for the Air Force, describes the efforts relevant to these population groups, and identifies the efforts most relevant to the USAF in its cleanliness standards development.

3.1 Uncertainties

Several obstacles lie in the path to certainty. One obstacle exists in the toxicology research methods themselves. In order to obtain statistically valid results from small groups of animals, large doses must be administered. Scientists then extrapolate the results using toxicological principles to estimate the risk of low levels of chemical agents to humans. Other problems lie in the fact that it is difficult to determine exposure levels that may cause adverse health effects after different durations and frequencies. The effects themselves may also be a mixture of delayed, immediate, transient, and chronic symptoms that have different characteristics at different exposure levels.[13]

It is difficult to recreate the varying environmental conditions in a laboratory in order to perform the proper testing. It is also possible that more than one type of chemical may be used simultaneously in an attack. Determining the effects from the interaction of two or more chemicals on humans is one of the most complex tasks in toxicology. Thus, specific caution must be taken when extrapolating results from the laboratory to the real environment.[14]

Another reason that acute-exposure standards have not yet been set is that the human-toxicity estimates for common CW agents were originally developed for offensive purposes.[15] The estimates were used to predict the number of casualties likely to occur with the offensive use of chemical weapons. These estimates were conservative; thus they understate the toxicity and are inappropriate to protect soldiers and civilians.

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[13] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 4.
[14] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 10-12.
[15] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 1-2. http://books.nap.edu/books/0309057493/html/1.html.

3.2 Efforts to Define Harmful Levels and the Resulting Toxicity Estimates

Despite the uncertainty that exists in determining toxicity levels for CW agents there have been and continue to be efforts to determine them. These efforts provide guidance in determining cleanliness standards necessary to protect different groups of people.

3.2.1 DEFINING THE POPULATION GROUPS OF CONCERN

Whether or not a chemical agent will cause harmful effects depends on the agent's concentration, the characteristics of the affected people, and the extent of protection donned by the affected people.[16] In the specific context of this report (developing a cleanliness standard for aircraft and equipment upon return to the US), the Air Force must be concerned about a broader population than deployed personnel. Deployed personnel work in a very different environment than personnel who are not deployed. While deployments may last from a period of days to a period of months, personnel who are not deployed may work in the same environment for periods up to four years. On a day to day basis, personnel who are not deployed typically do not work as many hours as deployed personnel. Also, in deployment situations, the Air Force is generally only concerned with military personnel (no retirees). In all other situations, however, the Air Force transports military and civilian equipment, military personnel (active, reserve, and retired), and their dependents, and civilians. For the purpose of this report, then, the Air Force must be concerned with protecting people of all ages, sexes, races, ethnicities, and health conditions (the general population). This consideration applies not only to those who may be transported by the Air Force, but also to those who may be transported by CRAF aircraft (if the aircraft are allowed to return back to commercial service). Additionally, the Air Force must consider the general population when disposing of the remains from decontamination processes.

Thus, the Air Force must examine three populations to be protected:

(1) Military personnel/workers in protective gear
(2) Military personnel/workers without protective gear
(3) General population

This report will not discuss the possibility of protecting civilians with protective gear due to the small likelihood that any civilian would agree to fly in a plane if protective gear was required. The protective gear must also be fitted correctly in order to protect a person. Although the gear comes in small, medium, and large sizes, it is not likely that the military would be able to outfit the necessary range of civilians (infants to elderly) with well fitting protective gear.

[16] The effects also depend on environmental factors, but this report assumes that the concentration determined to be safe will be safe in any environmental condition.

The three populations of concern differ in several manners. Military personnel tend to be healthier than the average person in the general population and they range in age only from 18-55. Military personnel in protective gear are also less vulnerable to chemical agents than those without gear, assuming that the protective gear functions correctly. Given these differences, the next sections will explain how the existing toxicity estimates or efforts to define these estimates apply to these three populations.

3.2.2 TOXICITY LEVELS FOR MILITARY PERSONNEL IN PROTECTIVE GEAR

Non-persistent agents present a low risk to personnel in full protection gear. If decontamination measures are performed quickly, persistent agents also pose a low or negligible risk.[17] Thus, the toxicity levels permissible for military personnel depend on the protective capabilities of the specific gear and the chemical agent in question. It is important to note that blood agents degrade the capabilities of protective masks.[18] Exposures with blood agents should therefore be minimized even for military personnel in protective gear.

3.2.3 TOXICITY LEVELS FOR MILITARY PERSONNEL WITHOUT PROTECTIVE GEAR

This report examined the Army's Permissible Agent Hazard Concentrations in Air, the CDEPAT estimates reviewed by the National Research Council (NRC), the Stimson Center's toxicity estimates, the Mitre reports, the Army's short-term exposure guidelines (USACHPPM TG230A), and the Army's current development of long-term low-level effects (USACHPPM TG230B) (See Appendix A). Additional research efforts concerning toxicity levels are being undertaken by other organizations. Their focus and specific topics are described in Appendix B.

After reviewing these standards, this report concluded that the only inhalation vapor standards appropriate for Air Force application are the Army's Permissible Agent Hazard Concentrations in Air, which the Army uses in its chemical agents and munitions destruction facilities. The other vapor inhalation standards and guidelines do not address non-deployed personnel or the general population. The Army's concentrations are the most applicable to the Air Force in setting its cleanliness standards for aircraft and equipment because they most closely simulate the conditions that the personnel will be exposed to. The levels are based on eight-hour exposures to the agents whereas all other available guidelines are for deployed military personnel only.[19] The permissible levels for military personnel without protective gear are presented in Table 1.

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[17] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 16.
[18] U.S. CIA. *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper. 1998. P.26.
[19] Deployed military personnel face a different environment than the three population groups defined in this report. Deployed military personnel would be exposed to CW agents for different durations and under different conditions than these other three populations.

The NRC reviewed estimates also show that percutaneous vapor exposures for the given CW agents are not harmful at the inhalation vapor concentrations (See Table 8 for details). Therefore, the permissible vapor concentrations are determined by the inhalation vapor concentrations shown in Table 1.

This study also determined that the NRC review of the CDEPAT toxicity estimates provides the best estimates for the Air Force to use as interim standards for protecting workers/military personnel from percutaneous threats from liquid chemical agents.[20] Unfortunately, the NRC reviewed estimates were only determined for liquid doses causing defined effects on the skin of the healthy military male; toxicity data does not exist for females. It is for this reason that this toxicity data should only be used as interim standards until data for females are developed. See Table 1 for these interim concentrations.

3.2.4 TOXICITY LEVELS FOR UNPROTECTED CIVILIANS (THE GENERAL POPULATION)

Toxicity values for the general population have not been published by the Environmental Protection Agency (EPA), the American Industrial Hygiene Association (AIHA), the Department of Energy (DOE), the American Conference of Governmental Industrial Hygienists (ACGIH), and the National Institute for Occupational Safety and Health (NIOSH) because contamination from chemical warfare agents has traditionally been a concern unique to the military.

The Army has published values for permissible agent concentrations in air for use in destroying chemical agents and munitions. These values meet the requirements necessary to protect the general population from the inhalation of vapor chemical warfare agents.[21] These inhalation vapor concentrations also suffice to provide protection from skin contact (percutaneous) with the vapors of the given chemical warfare agents. Table 1 presents these concentrations.

The only available toxicity data for liquid chemical warfare agents' effects on the skin, however, are not sufficient to protect the general population from harmful effects because these estimates have only been determined for healthy military males. Therefore, if liquid chemical agents are present, the aircraft and equipment cannot be used by the general population until better toxicity data is available.

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[21] Note that concentrations of chemicals in USACHPPM TG230A that are necessary to produce acute immediate or short-term effects are closer to occupational or emergency exposure guidelines than to ambient environmental air quality criteria or standards meant to protect the general population against chronic health effects from a lifetime of low-level exposure.

Table 2. Permissible Agent Hazard Concentrations

Agent[22]	Workers/Military Personnel Without Protective Gear		General Population	
	Inhalation Vapor[23] (mg/m^3) (8-hour exposure)	Percutaneous Liquid[24] (ED_{50}, mg for a 70 kg man)** INTERIM STANDARD ONLY	Inhalation Vapor[25] (mg/m^3) (72-hour exposure*)	Percutaneous Liquid
GA	0.0001	880	0.000003	Undetermined
GB	0.0001	1000	0.000003	Undetermined
VX	0.00001	2.5	0.000003	Undetermined
H/HD/HT	0.003	600	0.0001	Undetermined
L	0.003	----	0.003	----

*The sample air must have an agent concentration of less than the specified level for 72 hours.[26]

**Liquid percutaneous dose causing a defined effect in 50% of the exposed animals.

[22] Toxicity data for other agents that the Air Force is concerned about need to be researched.

[23] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington D.C., 1993. p. 82.

[24] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 1-2. http://books.nap.edu/books/0309057493/html/1.html.

[25] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington D.C., 1993. p. 82.

[26] These values may be more protective than necessary for the Air Force in transporting people (in general, the probability that a person would be on a plane for 72 consecutive hours is extremely low).

4. DECONTAMINATION

Once the Air Force determines that chemical warfare contamination has occurred to a level that is harmful to humans, it must then determine how it will decontaminate the materials. Chemical agents present a particular problem in that they are soluble in paint, plastics, and rubber. If chemical agents penetrate these substances or the ground, they may release toxic gases for long periods. Thus, it is important that the chemicals are either allowed to self-decontaminate or are removed by other decontamination methods.

This section addresses these decontamination methods, their problems, and the research aimed at addressing those problems. It will then suggest how the Air Force might utilize future technologies for its decontamination needs.

4.1 Self-Decontamination

Chemical agents will self-decontaminate over time. This process can be thought of as aeration. In some cases aeration may fulfill the Air Force's need for decontamination, especially in cases where only an aircraft's exterior has been contaminated. In other cases, the Air Force may need to use the equipment or aircraft before it has had sufficient time to self-decontaminate. The time period necessary to self-decontaminate depends on the chemical's natural chemical degradation time, the viscosity (thickness) of the agent, the surface upon which the chemical agent lies, and the level of absorption that has occurred into that surface. The time period is also dependent upon environmental factors such as temperature, wind velocity, humidity, and precipitation.[27] Table 2 gives approximate self-decontamination times for Soman, Mustard, and VX at 15°C, 4 m/s, and 2mm large droplets.

[27] Swedish National Defense Research Unit (FOA). Briefing Book on Chemical Weapons, 1992: Decontamination of Chemical Warfare Agents. p. 4. http://www.opcw.nl/chemhaz/decon.htm.

Table 3. Chemical Self-Decontamination Times[28]

SUBSTANCE	NO CONTACT RISK	
Metal Surface (Untreated)		
	Liquid*	Gas
Soman	<5 hours	<5 hours
Mustard Agent	<20 hours	<20 hours
VX	6-8 days	6-8 days
Metal Surface (Painted with typical non-resistant paint)		
	Liquid*	Gas
Soman	3-4 hours	1-5 days
Mustard Agent	1 day	3 days
VX	6 days	12-15 days

*Note: "The times for "liquid" only indicate when the surface is free of liquid, e.g., no liquid is transferred when touched. There is still a risk involved in contact and inhalation through release of gas from surfaces where the CW agent has penetrated deeply."[29]

The above table suggests that self-decontamination that occurs during transit from a contaminated forward area back to the US or to an allied country may sufficiently decontaminate the exterior of a plane. For example, an aircraft with a painted metal surface that has been contaminated with liquid soman should self-decontaminate if its flight time is four hours or more.[30]

4.2 General Decontamination Methods[31]

Self-decontamination will not always prove sufficient to protect humans from harmful effects, to prevent the spread of contamination, or to prevent the degradation of the contaminated surface. When it is insufficient, further decontamination must be performed. The purpose of any such decontamination method is to effectively and rapidly remove or render harmless poisonous substances on personnel and equipment. This can currently be performed in two ways: (1) physical removal and (2) chemical deactivation.

The *physical removal* of a chemical agent can be accomplished by flushing or flooding the contaminated area or entity with water that is free of detergent, soap, soda, or other additives. If the

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[28] Chem-Bio Reference. Chemical and Biological Detection, Analysis, Decontamination and Medical Response. p.18. http://chembio.janes.com/subscribe/reference/07detection.html 11/19/99 Taken from the FOA briefing book cited above. P. 4-5 of Decontamination section.

[29] Chem-Bio Reference. p.18.

[30] Aircraft travel much faster than 4 m/s. Thus, the four hour self-decontamination in flight time is very conservative.

chemical cannot be completely removed, it can be diluted to a harmless level. Water works well on most chemical agents, but it requires large water reserves and the residual solution may be toxic. Organic solvents such as fuel and paraffin can also be used. Chloramine solutions have been found to be effective against mustard and V-type agents, but they are ineffective against G-type nerve agents. Some rinsing substances, though, may erode, corrode, or etch the item's surface. Chemical agents can also be physically removed by evaporation, absorption, or heat treatment. Unfortunately, heat treatment may damage sensitive aircraft materials, electronics, or wiring systems.

Chemical deactivation can be accomplished by using a water/soap wash, oxidation, or an acid/base hydrolysis. Oxidation can be used against HD (mustard) and persistent nerve agent VX because they contain sulfur molecules. Hydrolyzation effectively deactivates the phosphorous groups that make up VX and other nerve agents (GA, GB, GD, and GF). Most chemical decontaminants, then, are designed to oxidize HD, but to hydrolyze nerve agents (GA, GB, GD, and GF).[32] Both oxidation and hydrolyzation deactivate VX.

4.3 Current Decontamination Capabilities and Problems

Current decontamination capabilities require the physical application and rinse-down of contaminated surfaces with decontaminants. For the decontamination of vehicles and other large objects steam and suspension and/or emulsion systems may be used. The C-8 Direct Application Decontamination System (DADS), developed by the Germans, prepares emulsion and then disperses it onto the vehicle or terrain.[33] The military services also use bulk caustic Decontamination Solution 2 (DS2), but this solution corrodes aircraft materials and electronics.[34] Fresh water and normal aircraft detergent solutions can be used to decontaminate the exterior of the aircraft without corroding the materials.

While these applications are effective against a wide variety of CW agents, they are not without problems. They do not allow for the decontamination of sensitive electrical equipment.[35] They are slow and labor intensive. They present safety and logistical problems and they also leave behind toxic residues.

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[31] Chem-Bio Reference. Chemical and Biological Detection, Analysis, Decontamination and Medical Response. p.16. http://chembio.janes.com/subscribe/reference/07detection.html 11/19/99.
[32] U.S. Army Research Institute of Chemical Defense. Decontamination. p. 4. http://206.39.77.2/DMCR/NBC/chemcas/decontam.htm
[33] Swedish National Defense Research Unit (FOA). Briefing Book on Chemical Weapons, 1992: Decontamination of Chemical Warfare Agents. p. 4-6. http://www.opcw.nl/chemhaz/decon.htm.
[34] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 15.
[35] Draft Statement of the Honorable Hans Mark. p.15.

Another problem inherent in decontaminating aircraft and equipment is that it is time consuming and difficult to decontaminate small cracks or crevices. Sometimes decontamination solutions may not diffuse completely into the small cracks or crevices. Heat can reach and destroy the agents in cracks or crevices, but it can also damage or destroy sensitive aircraft materials and electrical components.[36]

Additionally, if viscosity-increasing substances[37] have been added to the chemical agent they increase the agent's persistency and adhesiveness, making it difficult to decontaminate with liquids.[38]

4.4 Current DOD Research[39]

The Chemical and Biological Decontamination Program's (CBDP) goal and its research and development priorities directly address the aforementioned problems. The CBDP's goal is to "provide technology to remove and detoxify contaminated material without damaging combat equipment, personnel, or the environment."[40] Research and development priorities lie in finding non-corrosive, multi-agent decontamination and detection systems for large areas (such as air and sea-ports) combat equipment, cargo aircraft, ships, personal gear, and skin. All of the services also express interest in alternative technologies such as decontamination methods for sensitive equipment, large-scale automated decontamination systems, and catalytic coatings and sorbents. For near and mid-term applications, DOD is currently researching new multi-purpose decontaminants that are non-corrosive to replace DS2 and corrosive bleach. DOD research also includes sorbents, enzymatic foams, and reactive decontamination systems.[41] For far-term applications, DOD is trying to develop non-aqueous decontamination systems for sensitive equipment and for mobile sites.

4.5 Possible Applications of Other Technologies Under Development

The Air Force must evaluate any decontamination technology relative to existing capabilities. Areas for comparison include: non-corrosiveness; level to which the technology can decontaminate; effectiveness in cracks and crevices; toxicity of residues or end products; neutralization of multiple agents; stability in long-term storage; cost; mobility; ease of application; and speed of decontamination.[42]

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[36] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 84-5.

[37] Thickening agents such as oil, etc.

[38] Swedish National Defense Research Unit (FOA). Briefing Book on Chemical Weapons, 1992: Decontamination of Chemical Warfare Agents. p. 1. http://www.opcw.nl/chemhaz/decon.htm.

[39] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 15-16.

[40] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 15.

[42] These criteria were modified to apply to aircraft and equipment from the U.S. Army Research Institute Chemical Defense desirable traits of skin decontaminants which can be found at http://206.39.77.2/DMCR/NBC/chemcas/decontam.htm. p.2.

Other decontamination technologies in the developmental stages include Chemical Warfare Resistant Coating, Decon Foam 100, Canadian Aqueous System for Chemical-biological Agent Decontamination (CASCAD) Foam, Atmospheric Pressure Plasma Jet (APPJ), and a low-temperature decontamination system.

Chemical Warfare Resistant Coating is being developed by McDonnell Douglas Corporation. The coating is comprised of mixtures of modified siloxanes. When cured at room temperature, these siloxanes show minimal adverse effects after CW agent or simulant exposure. The coating can be applied to aluminum and is designed to be applicable to all areas of an aircraft, including the inside. The inventors claim that it will "exhibit minimal adsorption and/or absorption of chemical warfare agents and from which the agents can be readily desorbed by washing with soap and water."[43]

Thus, these coatings could be useful to the Air Force on both equipment and aircraft (interior and exterior) in easing the decontamination process. It may not be possible, though, to apply the coatings to aircraft materials or paints with specially designed properties (such as paint that may be used on the F-22 Raptor).

Decon Foam 100, currently under development by U.S. DOE Labs at Sandia National Laboratories, will neutralize a wide variety of chemical and biological agents.[44] It works by dividing the phosphate or sulfide bonds of chemical agents into nontoxic pieces. The foam can be dispensed from handheld canisters. As it is aerated and released through a nozzle, it expands to approximately 100 times the liquid volume and fills in the available space in small areas and in the air. After about two hours, the foam returns to its liquid state and is safe enough to be rinsed down any drain. The foam has successfully been tested in neutralizing simulants of chemical agents including VX, mustard, and soman. Tests show that the foam neutralized one half of the remaining chemical agent molecules every two to ten minutes, depending on the specific agent.[45] This foam is not harmful to humans and is relatively inexpensive (about 15 cents per pound, compared to the German nerve agent decontaminant costing $150 per pound).

The Air Force could use Decon Foam 100 on aircraft exteriors and equipment. One interesting advantage of this foam is that the remaining toxicity level can be estimated by the time of decontamination. This advantage may be beneficial to the Air Force because even if the battlefield detectors cannot detect to the required safety certification levels, the Air Force may be able to certify the equipment based on the known decontamination times of the foam. The foam may also expand into cracks and crevices that other decontaminants cannot reach.

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[43] Byrd, Norman R. (Inventor). Chemical Resistant Coatings. United States Patent: 5,858,468. McDonnell Douglas Corporation, St. Louis, MO. p.3..

[44] Worden, Emily. Chem-Bio News. "Decon Foam May Help Counter Chem-Bio Attacks." March 4, 1999. p.1-2. http://chembio.janes.com/subscribe/news/news_99-03-03.html.

CASCAD, under license from the Canadian government, has been tested on vehicles, equipment and surfaces by the Canadian forces and the French government. It is a broad-spectrum decontamination method that will destroy nerve agents in the G and V families, vesicants in the H and L families, along with biological agents. It eliminates off-gassing and the associated downwind hazards. It destroys CW agents in paint and can be mixed on-site with fresh or salt water. As the previous table illustrates, CASCAD compares favorably to DS2 and C-8 DADS for decontaminating aircraft exteriors and non-electrical equipment. The Air Force should look into using CASCAD instead of DS2 and C-8 until Decontamination Foam 100 is available. Before the Air Force uses CASCAD on aircraft made of sensitive materials, though, it should perform additional testing on CASCAD's corrosive effects on these sensitive materials (other than paint, rubber, and aluminum).

Table 4. Comparison of Decontamination Liquids[46]

Feature	**DS2 (Decontamination Solution 2)**	**C8-DADS (Direct Application Decontamination System (German))**	**CASCAD (Canadian Aqueous System for CB Agent Decontamination)**
Applied form	Clear liquid	Cloudy liquid	White foam
Delivered form	Clear liquid in quart containers	Multi-part liquid and powder requiring emulsifying	Powder and liquid
Additional Ingredients	None	Water	Water (fresh, salt, grey)
Destroys agents on surface Nerve- G, V Vesicants- H, L Biological Agents	 Yes Yes Yes	 Yes Yes Yes	 Yes Yes Yes
Destroys CW agents in paint	Not sufficiently	Not sufficiently	Yes
Toxicity of Residue	Highly toxic	Highly toxic	Non-toxic
Effect on typical surfaces: Paint Rubber Aluminum	 Removes Softens/breaks down Causes Pitting	 Removes some Softens Minor effects	 None None None
Typical Application Method	20 liter spray	500 gallon mixer: requires approx. 30 minutes	Continuous injection system, reloadable without shutdown. Draw from any available water source

[45] News Release, March 1, 1999: Sandia Decontamination Foam May be Tomorrow's Best First Response in a Chem-Bio Attack. p.2. http://www.sandia.gov/media/cbwfoam.htm.

The Atmospheric Pressure Plasma Jet (APPJ) is under production at Los Alamos National Laboratory.[47] The plasma that flows from the jet effectively neutralizes surrogates for anthrax spores (a biological warfare agent), mustard blister agent, and VX nerve gas. It may be suitable for sensitive equipment in vehicle interiors because it does not cause corrosion of most surfaces, nor does it damage most plastics, wiring, or electronics. The residue is also not harmful like the residue from other decontamination methods. When the APPJ becomes available, the Air Force can use it for decontaminating all objects of concern, aircraft exteriors and interiors and equipment.

Low Temperature Decontamination for Chemical and Biological Defense is being developed by the SELF Corporation under a Small Business Innovation Research Award from the Army.[48] A microemulsion specifically designed for low temperature applications will be used to develop an all temperature decontamination solution that is non-toxic, non-flammable, and environmentally friendly. This solution may be used as a replacement for the stockpiles of DS2, but it is not as advantageous as the APPJ because it cannot be applied to the aircraft interiors due to electrical concerns.

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[46] CASCAD Decontamination Foam. http://www.odel.on.ca/rsdl/cascad.html.
[47] Hans W. Herrmann. Session F3I2: Plasma Sources and Applications of Plasmas I. http://www.aps.org/BAPSDPP98/abs/s1900001.html 11/6/99.
[48] Army SBIR Award. Low Temperature Decontamination for Chemical and Biological Defense. http://www.aro.army.mil/arowash/rt/a_1page31.html 11/6/99.

5. CHEMICAL WARFARE AGENT DETECTION TECHNOLOGIES

Once the aircraft, equipment, or casualties have been decontaminated, the Air Force must use detectors to certify that they have been decontaminated to a safe level. This section describes the current detectors and their shortcomings. It then identifies the on-going and future research programs addressing these shortcomings. Finally, it states whether or not the current and future detectors have or will have the capability to certify to the appropriate level for the three populations that the Air Force must protect.

5.1 Current Detectors

The current battlefield detectors include the M8 and M9 Chemical Detection Papers, M8A1 Automatic Chemical Agent Alarm, M21 Remote Sensing Chemical Agent Alarm (RSCAAL), M22 Automatic Chemical Agent Detection Alarm (ACADA), Improved Chemical Agent Monitor (ICAM), M256A1 Chemical Agent Detector Kit , and the M272 Water Testing Kit.[49] These detectors are described briefly in Appendix F.1.

These existing systems have many shortcomings. They are labor-intensive, time-consuming, and are subject to false positive[50] readings. The systems are limited in their usefulness on aircraft, lack mobility, and are too sensitive to non-chemical warfare agent exposures (such as antifreeze, organic vapors, or electromagnetic interference).[51] In addition, the current battlefield detectors are not sensitive enough to provide low-level chemical hazard warnings. For example, the sensitivities of current battlefield vapor detectors for sarin range from 0.06 to 0.1 mg/m^3.[52] The Air Force needs to be able to detect the presence of chemical warfare agents in the range of 0.000003 to 0.0001 mg/m^3 in order to protect military personnel and the general population (see Table 1 in the CW Agent Levels Harmful to Humans section of this report). The required detectable level[53] to protect the general population from the harmful effects of inhaling sarin is 20,000 times lower than the most sensitive battlefield detector can currently detect.[54] The required detectable level to protect workers and military personnel from the harmful effects of inhaling sarin is 600 times lower than the most sensitive battlefield detector can currently detect.[55]

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[49] Chem-Bio Reference. "Chemical and Biological Detection, Analysis, Decontamination and Medical Response." p. 8-10. http://chembio.janes.com/subscribe/reference/07detection.html

[50] Detectors sometimes sense the presence of chemical agents when they are not actually there.

[51] GAO Report to Congressional Requesters, September 1998. Chemical Weapons: DOD Does Not Have a Strategy to Address Low-Level Exposures. p. 10.

[52] DOD Strategy to Address Low-Level CWA Exposures, May 1999. p.7.

[53] Defined by this report in the CW Agent Levels Harmful to Humans section.

[54] (Best battlefield detector's sensitivity)/(Level necessary to protect general population) = (0.06 mg/m^3)/(0.000003 mg/m^3) = 20,000

[55] (Best battlefield detector's sensitivity)/(Level necessary to protect general population) = (0.06 mg/m^3)/(0.000003 mg/m^3) = 600

5.2 Current and Future Chemical Agent Detection Programs

Current programs focus on fielding improved "point and stand-off detection systems to provide full coverage for individuals, ships, and aircraft with better reliability, enhanced sensitivity, and additional agent detection capability."[56]

Many of these developmental efforts have been separate efforts from disparate agencies, but over the past three years, with assistance from JPO-BD and through the contamination avoidance commodity area manager, JSMG and JSIG have consolidated efforts into the following joint programs:[57]

1. Automatic Chemical Agent Detector Alarm (ACADA described above)
2. Joint Chemical Agent Detector (JCAD)
3. Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD described above)
4. Joint Service Chemical Warning and Identification Light Detection and Ranging LIDAR Detector

Research on low-level chemical detection is being performed in several different areas. The JSMG is overseeing research on chemical agent alarms/sensors and continuous monitors. DOD funds multiple projects in this area, but the primary projects are lead by the Army's Edgewood Chemical Biological Center.

5.3 Mismatch of Capabilities and Needs

The current battlefield detection capabilities are not capable of certifying to the 3X and 5X levels (the levels necessary to protect military personnel/workers without protective gear and the general population) (See Table 4). The new JCAD will provide a sensitivity of 0.0001 mg/m^3. This level will be sufficient for the Air Force to protect working military personnel (with or without protective gear) from harmful effects due to the inhalation of GA, GB, H/HD/HT, and L. JCAD will not, however, provide the detection capability necessary to ensure the safety of the general population for these agents. Therefore, the Air Force must aim for continual improvements to produce battlefield detectors with sensitivities of 0.000003 mg/m^3 in order to protect the general population.

The Air Force focus on future improvements in detection technologies is on improved range and sensitivity, system miniaturization, decreased operations and support costs, and reduced false alarm

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[56] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 7.

[57] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 11 AND Chow, Brian G., Gregory S. Jones, Irving Lachow, John Stillion, Dean Wilkening, Howell Yee. RAND Corporation. "Air Force Operations in a Chemical and Biological Enviornment." Project AIR FORCE. DB-1891/1-AF. p. 74
http://www.rand.org/publications/DB/DB189.1/DB189.1.pdf/ 3/2/00

rates.[58] These improvements should address this mismatch between capabilities and needs. Until then, the Air Force should use of the laboratory analytical techniques employed by the Army's Chemical Agent and Munitions Destruction Facilities which can measure 0.0000006 mg/m^3 in certifying aircraft and equipment for use by the general population.[59] If this suggestion is not feasible, until the JCAD is ready, the Air Force will have to limit the use of contaminated equipment or aircraft to military personnel with protective gear (certify these aircraft and equipment at the 1X level). Once the JCAD is fielded, but until detectors can sense concentrations of 0.000003 mg/m^3, the Air Force will only be able to certify to the 1X and 3X levels. This limitation will restrict the use of the aircraft and equipment as described in Table 6 in the conclusion of this report.

[58] Draft Statement of the Honorable Hans Mark, Director, Defense Research and Engineering. DOD Chemical and Biological Defense Program, 10/13/99. p. 10.

[59] These analytical techniques are five times more sensitive than necessary to protect the general population from harmful effects.

6. CURRENT MILITARY DECONTAMINATION-RELATED POLICIES

The next step after identifying the problem, the chemical warfare agents and their effects, the harmful levels of these agents, and the available decontamination and detection methods, is to examine the current policies and guidelines employed by other sectors of the military and the military as a whole. This section outlines these policies and guidelines and describes their usefulness to the Air Force.

Current military decontamination-related policies focus more on the needs of operational decontamination than on a standard for resuming normal peacetime operations or for transiting to and landing in other countries. The policy for how clean is safe in war-time significantly differs from the question of how clean is safe for normal peacetime Air Force operations. Establishing a safe environment for military personnel in full protection gear to continue war operations is different from establishing a safe environment for the transport of civilian, unprotected workers/military personnel, and equipment; or for preventing the contamination of airfields in other countries.

The Air Force should keep this discrepancy in mind when looking at the approaches of the Joint Staff, DOD, U.S. Army, and U.S. Navy discussed below. The Army's approaches are of particular interest to the Air Force and can be adapted to meet the needs of the Air Force.

6.1 Joint Staff

The DOD interim chemical standard issued by the Joint Staff echoes the radiation standard: if it is not detectable, it is not there. Thus, equipment is "clean" when you can no longer detect any chemical contamination.[60]

This interim standard poses two dangers. First, the detectable level of a chemical depends both upon the detection equipment used and the chemical agent in question. For example, the battlefield detection systems are much less sensitive than those detection systems used in laboratories or in chemical munitions destruction facilities. Thus, it is not sufficient to say that an aircraft is clean when you cannot detect any chemical contamination without specifying which detection equipment must be used. For example, the current battlefield detectors for detecting sarin range in sensitivity from 0.06 to 0.1 mg/m^3. This renders battlefield detectors useless in detecting the presence of the concentration level of 0.0001 mg/ m^3 (or 100 ng/m^3),[61] which is necessary to protect the workers/military personnel without protective gear from experiencing harmful effects by inhaling sarin.[62] Thus, it is not sufficient to use battlefield

[60] David Grube and Lt Col Jimmie of AMC. E-mail. 12/3/99.

[61] 1 mg = 10^6 ng. Therefore, 0.000003 mg/m^3 = 3 ng/m^3.
mg stands for milligram which equals one thousandth of a gram
ng stands for nanogram, which equals one billionth of a gram

[62] See Table 1.

detectors to certify an aircraft as clean enough to protect the health of the maintenance people who must work on the aircraft or the people (military and non-military without protective gear) and equipment that will be transported by the aircraft. On the other hand, if the Air Force could use the same detection equipment that the Army uses in its chemical munitions destruction facilities, the Air Force could detect levels down to 0.6 ng/m^3. This level is well below the harmful level of 100 ng/m^3 for workers/military personnel exposed to sarin is even sensitive enough to protect the general population against hazards (permissible level in air of 3 ng/m^3 for 72 hours).[63]

The second problem inherent in the DOD interim standard is that the level of a chemical warfare agent that is harmful to humans is independent of the detection technology used to detect its presence. With advances in technology, battlefield detectors will become more sensitive. Their sensitivity levels may extend beyond the needs of detecting permissible safety levels.[64] A standard that hinges on the detection capabilities may impose unnecessary restrictions in the future. Also, as the detection technology becomes more sensitive, it is subject to more false positives.[65] If the cleanliness standard is tied to the detection capability, the Air Force may spend unnecessary time and resources decontaminating.

6.2 DOD

In response to a General Accounting Office report stating the lack of a low-level doctrine for DOD, DOD produced a report titled, "Strategy to Address Low-Level CW Agent Exposures." While this report does not address the full needs of the Air Force because it is focused on deployed military personnel, it has two components that may be valuable to the Air Force. First, its suggestion to evaluate any policy in light of other agency requirements also applies in the Air Force's situation. Second, its research and development plan will also be helpful to the Air Force. The Air Force must expand upon this research plan, though, to include research on detection and decontamination technologies that are capable of making aircraft and equipment safe for the general population.

The DOD strategy defines low-level exposures for DOD-wide usage as implying both a chemical concentration and a type of effect dependent on an assumed duration of exposure (Appendix C). The definition is focused on an application for deployed military personnel, which does not suffice for the Air Force to resume normal operations upon return to the US.

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[63] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 82.

[64] In theory, this does not seem like a problem. But, as Richard McNally of SAIC pointed out in an e-mail on 11/12/99: At the time that the radioactive lowest detectable standard was accepted, "the detection threshold was appropriate for providing safe levels of exposures. Today, detection capability for radioactivity has become so sensitive that background levels can be picked up orders of magnitude below any reasonably safe level." This increase in sensitivity has lead to unnecessarily restrictive rules and procedures.

[65] The detectors may signal that tiny concentrations are present, when in actuality the object or air is clean.

Section II of this strategy provides a fairly comprehensive review of current policy, doctrine, and guidance concerning chemical and biological agents. The strategy also suggests that any policy must be evaluated in light of requirements from non-DOD agencies or organizations. It suggests that one mechanism for disseminating non-DOD guidance will be the North Atlantic Treaty Organization Preventive Medicine Working Group established under PRD-5[66]

The DOD Strategy to Address Low-Level CW Agent Exposures also provides a strategy for research, development, and policy development for low-level chemical exposures.

6.3 U.S. Army

"The U.S. Army, by regulation, establishes the occupational and general population exposure limits [for chemical warfare agents] and they are accepted by regulatory organizations in the US."[67] The Army imposes special regulations, not imposed by regulatory organizations, because of the extremely toxic nature of chemical warfare agents.[68] The Army has established standards or guidelines in the following three areas: handling chemically contaminated casualties, chemical warfare agents and munitions destruction, and short-term chemical exposure guidelines for deployed military personnel. It is also working on long-term chemical exposure guidelines for deployed military personnel.

The short-term and long-term chemical exposure guidelines are focused on deployed military personnel. This focus is not sufficient for the Air Force. Therefore, these guidelines will not be discussed in this section (See Appendix A for details on each set of guidelines).

6.3.1 HANDLING CHEMICALLY CONTAMINATED CASUALTIES

The Army has established guidance procedures for the handling of chemically contaminated casualties. These procedures have been accepted throughout the services. DOD regulation 6055, 9-STD, Army Regulation 385-64 (Ammunition and Explosives Safety Standards), Army Pamphlet 385-61, and Army Training and Doctrine Command (TRADOC) Regulation 385-1 provide guidance for determining the effectiveness of decontamination. The existing guidance establishes levels of decontamination. Materials must be decontaminated to the 3X level and repatriated to the continental United States to remain under the federal government's control. This mainly restricts the burial of 3X-level human remains in to federal cemeteries, for the only method of decontamination is cremation.[69] Certification that

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[66] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 29.
[67] Richard E. McNally of SAIC. E-mail. 11/12/99.
[68] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 81.
[69] Joint Procedures for Decontaminating Human Remains. p.8. http://www.gulflink.osd.mil/cgi-bin/texis/searcj/gulfsearch/~njvezzsqCCJJbesco1h.../view.htm 12/4/99.

a casualty has been decontaminated is accomplished by processing through a decontamination facility, M-8 paper, M-9 tape, M256A1 ticket, and a Chemical Agent Monitor (CAM).[70]

The Air Force has accepted and should use these procedures to handle chemically contaminated casualties.

6.3.2 CHEMICAL WARFARE AGENTS AND MUNITIONS DESTRUCTION

The Army has also established performance standards for the destruction of chemical agents and munitions.[71] It requires chemical agent destruction technologies to meet worker protection, ambient air quality control, and liquid and solid waste control standards. The U.S. Department of the Army generated these standards in cooperation with the NIOSH and the EPA. The governing laws include the Occupational, Safety and Health Act, the Resource Conservation and Recovery Act, and the Toxic Substances Control Act. The Army imposes the following special regulations due to the extreme toxic nature of chemical agents:

Worker Standards: The Army designs all handling processes to prevent worker contact with the chemical agent. Workers must use full-body, plastic protective suits (Demilitarization Protective Ensemble) into which they are sealed. For work in contaminated areas where the airborne exposure would likely exceed the maximum permissible level for workers (see Table 1 in Harmful Levels of Chemical Agents Section) this suit includes a remote clean air supply.

Air Quality Standards: The Army has also established permissible hazard concentrations as air quality standards for each chemical agent and location.

Liquid Wastes: With regards to liquid wastes, state and community standards for water effluents and drinking water must be satisfied. Most contaminated water should be recycled internally in the plant processes for practical reasons.

The Army has self-imposed categories of chemical agent contamination of solid wastes.[72] Just as the Army has a concern for releasing the material to the general public, the Air Force also has a concern in certifying its aircraft and equipment for use by the general public. This three-tier approach would serve the Air Force well in its decontamination policy.

Thus, this report suggests that the Air Force adapt the Army's contamination levels to apply to the USAF needs in the following manner (significant modifications are italicized):[73]

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[70] U.S. Army Research Institute of Chemical Defense. p.3. http://206.39.77.2/DMCR/NBC/chemcas/decontam.htm.
[71] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 81.
[72] These wastes include waste salts, dunnage, wood pallets, metal parts, etc.
[73] The original level descriptions can be found in Appendix G. They were taken from: National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 82-3.

- **Level 1X**: Contaminated material that has not yet been decontaminated or material that still contains detectable agent levels at or above the permissible levels for workers/military personnel.[74]

- **Level 3X**: Potentially contaminated material or previously contaminated material that has been decontaminated to show concentrations below the permissible levels for workers/military personnel.[75]

- **Level 5X**: Fully decontaminated material that shows concentrations below the permissible levels for the general population. Level 5X materials must have undergone heat treatment of at least 1000° for at least 15 minutes or *a similar process that ensures the destruction of any residual agent that may be inaccessible to chemical treatment in cracks or crevices.*

The permissible levels referred to in the above definitions can be found earlier in this report in Table 1.

The Army is also considering alternative treatment processes that may meet the 5X requirement.[76] It is exploring higher temperature heat treatments for shorter times and low-temperature alternative technologies. The low-temperature alternative technologies would be of particular interest to the Air Force due to the sensitive nature of aircraft materials. Specifically, the Army is considering a new alternative 5X standard for destroying GA and GB nerve agents associated with local accidents, the contamination that results, and the reoccupation of evacuated (because of contamination) housing. This standard parallels the Air Force needs for successful decontamination that would be suitable for the general population and that would not damage the physical structure or characteristics of the objects being decontaminated. The Army's alternative would subject the residual material to appropriate tests, which have not yet been defined, but that would show that the air over the sample has an agent concentration of less than 3 ng/m^3 for 72 hours (meeting the air quality standard for the general population). This standard could not apply to mustard agent (HD) because it is carcinogenic. This new standard is also not intended for application to the primary operations at chemical agent destruction facilities. It is intended only for accidents. In the USAF's case, a similar standard would also not be common practice, but would only be employed in the case of an enemy's use of chemical warfare.

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[74] For Level 1X and Level 3X the level of chemical agent present is to be determined by air monitoring above the material or by approved aircraft detection methods.

[75] Same as footnote 54.

[76] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 83.

6.4 U.S. Navy

The Naval War College possesses a book concerning environmental issues in armed conflicts called, Protection of the Environment during Armed Conflict and Other Military Operations,[77] James Terry also wrote on the environmental issues in The Impact of Desert Storm in The Environment and the Laws of War. This report did not explore these publications.

[77] Dwight Moore, USTC JA. E-mail. 3/9/00. It can be found in Naval War College. Catalog. http://205.67.218.5/press/catalog/bluebook.htm.

7. REGULATORY AGENCY STANDARDS AND CONCERNS

After examining the other military decontamination-related policies, the Air Force must recognize the standards and concerns of U.S. regulatory agencies and international liability concerns.

7.1 Regulatory Agency Toxicity Standards

Published toxicity values from the EPA, AIHA, DOE, ACGIH, and the NIOSH are not available for most chemical warfare agents because of their unique military purpose.[78]

Chemical agent destruction standards, though, are generated by the U.S. Department of the Army in concert with NIOSH and EPA. These standards are detailed in Table 1 in the section of this report titled CW Agent Levels Harmful to Humans. The governing laws for chemical agent destruction include the Occupational, Safety and Health Act, the Resource Conservation and Recovery Act, and the Toxic Substances Control Act.[79]

7.2 Regulatory Agency Concerns

Although the regulatory agencies do not have published toxicity values, they do have an interest in the USAF decontamination policy. The Federal Aviation Administration (FAA) is the U.S. agency with the most concern about an Air Force decontamination policy. The other agencies, such as NIOSH and EPA, will be interested in the exposure of workers and the general population to harmful levels of chemical agents. If the Air Force uses the Army's pre-approved levels (discussed in the Harmful Levels section of this report), this should satisfy the NIOSH and the EPA. The NIOSH also has a method for determining toxicity levels from unreliable data that the Air Force might use to employ to extrapolate data from population to population (such as for the undetermined percutaneous liquid hazards in Table 1 of this report). Appendix E provides a comprehensive review of each of the regulatory agencies that may have concerns relevant to decontamination policy considerations, but only the specifics of the FAA will be discussed below.

7.2.1 FEDERAL AVIATION ADMINISTRATION (FAA)[80]

The Federal Aviation Administration focuses on three mission goals: safety, security, and system efficiency. It strives to reduce the occupant risk (reducing the risk of mortality to a passenger or flight crewmember on a typical flight.)[81]

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[78] USACHPPM TG230A. Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999. http://chppm-www.apgea.army.mil/imo/ddb/dmd/dmd/TG/TECHGUID/TG230A.PDF p. 16.
[79] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington D.C., 1993. p. 81.

The FAA is intricately involved in the Civil Reserve Air Fleet. It has stakes in decontaminating the CRAF planes so that they can safely return to commercial service upon return from a forward-deployed area. It is also concerned with the contamination of commercial airfields.

Currently, the FAA does not think it is possible to return the once-contaminated planes back to commercial service. The FAA believes that even if decontamination is possible and performed, passengers will not be willing to fly on the aircraft.

The FAA flight safety standards prevent, as much as possible, the use of CRAF in potential CW environments (demonstrated in Desert Storm and in Somalia). Should an aircraft become contaminated, the FAA would like the aircraft to use a DOD airfield instead of contaminating and thus shutting down a commercial airfield.

If the commercial insurance market refuses to insure the aircraft, which is highly likely with the threat of a CW environment, the FAA provides war risk insurance to the CRAF suppliers. If a CRAF aircraft is contaminated with a persistent chemical agent that will not submit to the normal decontamination methods of aging or cold soaking at altitude, the FAA has indicated that DOD will be required by law to reimburse the FAA for any pay out of the insurance fund for this CRAF loss. The FAA also believes that the mechanics will be unwilling to work on an aircraft due to the fear of drilling into or coming into contact with a contaminated area that the decontamination method may have missed.

Due to the aforementioned concerns, the FAA does not feel that it will use a decontamination policy for CRAF aircraft resuming civilian operations if the Air Force makes one. The FAA will consider any CRAF aircraft that become contaminated as a loss. This stance is held by both the FAA insurance personnel and FAA flight standards personnel who both possess equal input on CRAF issues.[82]

On the other hand, the FAA sees the need for a cleanliness standard for allowing contaminated or decontaminated aircraft to land on commercial airfields. It may be willing to accept such a standard after it has been researched and established by the USAF.

7.3 International Law and Liability Issues

Not only must the Air Force be concerned with U.S. regulatory agencies, but it also must be concerned with adhering to international law and any liability issues that may result. This adherence is necessary in order to establish a decontamination policy that the international community will accept. General Robertson of the United States Commander-in-Chiefs, TRANSCOM, emphasized this importance at a Commander-in-Chief's conference late in 1999 when he stated that "potentially the most

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[80] Except where otherwise noted, all information in this section was taken from an e-mail from Dwight Moore, USTC JA, on 3/9/00.
[81] FAA. Safety, Security, and System Efficiency. http://www.faa.gov/safety2.htm. 3/11/2000.
[82] Dwight Moore, USTC JA. E-mail. 3/9/00.

significant issue facing the Defense Transportation System today is the lack of an internationally accepted cleanliness standard."[83] The implications of this lack of a standard can significantly restrict time phase force and deployment data throughput. Cleanliness certification meeting international standards will also help eliminate possible landing and transloading problems in foreign countries during wartime and when returning through an allied country back to the United States.[84]

International law is primarily focused on punishing the agressor or CW user. It does not place standards on the victim for decontaminating in a foreign country. The US may be held strictly liable, though, when transiting back to the US and landing in other countries for knowingly transporting hazardous materials. In July 1998, USTRANSCOM met with the FAA, DOD, Joint Chiefs of Staff, USAF and Federal Emergency Management Agency representatives about this issue of moving a contaminated aircraft and contaminating a civilian runway in another country.[85] They determined that in this instance, the US would pay for any and all damages. Thus, in order to prevent having to pay for damages, the US must develop a decontamination policy that can be internationally accepted and must seek this acceptance.

[83] David Grube and Lt Col Jimmie Jacobs of AMC. E-mail. 12/3/99.
[84] Col (Select) Marcelyn Atwood (then of AF/XONP) indicating Brigadier General Bob Smolen's (of AF/XON) concerns about decontamination certification in an e-mail dated 15 Nov, 1999.
[85] Dwight Moore, USTC JA. E-mail. 3/9/00.

8. AIR FORCE "SAFE" CRITERIA

After examining the involved issues, this report now defines six criteria for evaluating any Air Force policy on decontamination certification. These criteria follow:

1. Prevention of health risk to humans
2. Prevention of the spread of contamination to equipment and to returning bases/locations
3. Minimization of mission impact
4. Political feasibility
5. Technological feasibility
6. Minimization of costs

8.1 Prevention of Health Risk to Humans

The Air Force must be concerned with long-term low level effects and the effects of multiple exposures on humans. The aircraft will be used to transport unprotected military personnel, retired military, military dependents, and selected civilians. The Air Force is also concerned with the ability to decontaminate CRAF planes well enough to allow them to return to commercial operations in which they will be transporting civilians of all ages, sexes, races, ethnicities, and health conditions. The Air Force must also be concerned about the health risks of those who handle contaminated casualties. Thus, the Air Force must be concerned with protecting the following three populations, classified similar to the Army's classification for its chemical agents and munitions destruction facilities:

1X: Workers/Military personnel in protective gear
3X: Workers/Military personnel without protective gear
5X: The general population

The Air Force must adhere not only to the cleanliness standards for the aircraft, equipment, personnel, and casualties, but also for the handling or disposal of solutions left after decontamination. It must ensure that these solutions will not pose contamination or health risks.

The Air Force must also be concerned with chemical agents such as blood agents that warrant special considerations. Blood agents degrade the effectiveness of protective masks.[86] This fact must be taken into consideration by imposing special restrictions when blood agents are present.

8.2 Prevention of Spreading Contamination to Equipment and to Returning Installations

When contaminated aircraft, equipment, personnel, and/or casualties are returning to the US (directly or via an allied country), the Air Force must be concerned about the contamination of clean

airfields, personnel, and equipment that may be contaminated by direct contact with the contaminated entity or by off-gassing. When the aircraft return to normal mission operations they will be used to transport civilian and military equipment to and from civilian and military locations.

8.2.1 ACTIVITIES THAT MAY SPREAD CONTAMINATION

Loading or Unloading clean equipment, personnel, or casualties on or from a contaminated aircraft could contaminate the equipment, personnel, or casualties. Likewise, loading or unloading contaminated equipment, personnel, or casualties on or from a clean aircraft could contaminate the aircraft. *Precautions* available to prevent spreading contamination in this manner include covering all equipment with CW resistant material during loading and unloading; disposing of this material properly at the receiving location; and using detectors to re-certify the aircraft that has transported contaminated equipment or the equipment that has been transported by a contaminated aircraft.

Performing maintenance on contaminated aircraft or equipment could contaminate the tools or harm the maintenance personnel. *Precautions* available to prevent spreading contamination in this manner include decontaminating (to the 5X level) any tools that have been used on contaminated aircraft or equipment; and requiring maintenance workers to wear protective gear. (In some cases, wearing protective gear may not be feasible.)

Taking off could contaminate the immediate area with spray from the aircraft. *Precautions* available to prevent spreading contamination in this manner include not allowing the aircraft to take off until it has been decontaminated. If the local area is already contaminated, which is highly probable, then this should not be a concern because the aircraft should not contaminate the local area anymore than it is already contaminated.

Landing a contaminated aircraft on a clean airfield could contaminate that airfield. The possibility of spreading contamination to clean airfields or equipment when an aircraft with a contaminated exterior arrives at a new location depends on several factors. These factors include the chemical agent in question; the viscosity of that agent; the agent droplet size; the material surface upon which the chemical agent lies; the transit time from the forward area back to the US; the speed at which the aircraft traveled; and the existing environmental conditions. The various chemical agents have different self-decontamination times (as discussed in the decontamination section of this report) that depend upon the size of the chemical droplet, the temperature, and the wind speed. In general, the variations in the factors affect the possibility of spreading contamination at a receiving base as summarized in the following table:

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[86] U.S. CIA. *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper. 1998. p.26.

Table 5. Effect of Variables on the Possibility of Spreading Contamination to a Clean Airfield

Variable	Change in Variable	Effect on possibility of spreading contamination
Transit Time	Increased	Decreases possibility
Aircraft Speed	Increased	Decreases possibility
Temperature at returning airfield	Increased	Increases possibility

Precautions available to prevent spreading contamination in this manner include flying the aircraft for the required amount of time to allow it to self-decontaminate; decontaminating the aircraft to a level sufficient to prevent contamination from spreading (Level 3X should be sufficient);[87] and restricting the allowable landing locations for the aircraft.

Transferring or using contaminated equipment could contaminate the users or facilities. *Precautions* available to prevent spreading contamination in this manner include covering the equipment during transfer/transport and restricting the user population.

Decontaminating could leave behind toxic residue that could contaminate the environment or pose a health risk. *Precautions* available to prevent spreading contamination in this manner include decontaminating in an area that is already contaminated (probably the area where the contamination occurred) and using special decontamination technologies that do not leave behind toxic residues.

Disposing of equipment, aircraft, or casualties that will not be decontaminated could contaminate the environment. Specifically, incinerating could produce toxic gases. Dumping the equipment or aircraft in large bodies of water could contaminate the water. Using a landfill may not be practical due to the size of aircraft or equipment. *Precautions* available to prevent spreading contamination in this manner include using approved incinerating methods or quarantining the aircraft for a time period and in such conditions sufficient for self-decontamination to occur.

8.3 Minimization of Mission Impact

The Air Force must determine how clean its equipment must be to carry on mission essential operations without harming personnel or degrading equipment. Any policy must allow decisions to be made according to each specific situation due to the complexity brought on by the many different types of chemical warfare agents and the many different situations that can exist.

There must be a balance between providing adequate protection and avoiding any low-level exposure to CW agents.[88] A decontamination policy should allow the mission to be carried out if it can be done by personnel wearing protective gear and without posing any undue health risks or spreading

[87] The author assumes that any amount of contamination that will spread will be much lower than the 3X level and therefore will not present a hazard to any of the three populations.

contamination. Some protective gear, however, may reduce the performance of personnel especially under the space and mobility constraints that exist in an aircraft.[89]

CW agents may cause the corrosion of aircraft materials and structures, the swelling and degradation of seals, insulation, and transparencies, and the deterioration of avionics components and wiring.[90] Some decontamination solutions may also damage aircraft. The Air Force must evaluate if the CW agents or the decontamination process will damage the equipment or aircraft enough that it is no longer usable to carry out the Air Force mission.

In balance with the other criteria, the policy should strive for minimal impact on mission essential operations, while still providing a safe environment for the three populations described above.

8.4 Political Feasibility

The Air Force policy must be reasonable according to the other military services and other regulatory agencies (national and international).

It is necessary to have a DOD-wide policy because the Air Force is the single manager of airlift for all of the military services. Therefore, the Air Force may have to transport another service's equipment. If this equipment is contaminated, each service must have the same cleanliness standards to ensure consistent safety measures.

With regard to other regulator agencies, it is useless to set cleanliness standards if regulatory agencies will not agree to allow operations under those conditions. For example, it is useless to certify CRAF aircraft to the 5X level if the FAA will not allow CRAF aircraft to re-enter commercial service even if they have been decontaminated. The Air Force must be aware of any legal concerns that may arise with aircraft rendered unusable or aircraft damaged in the decontamination process. The Air Force must also consider any problems that may arise from psychological fears. For example, civilians may refuse to fly on a CRAF aircraft that they know has been through a VX attack, even if it has been sufficiently decontaminated. The Air Force must help the agencies and the general public understand the difference between chemical warfare agents and biological warfare agents. The threat of psychological fear is greater with biological warfare agents than it is with chemical agents. For example, although contaminated biological laboratories have gone unused for years, the public returned to using the Tokyo subway system shortly after the sarin attack was cleaned up.[91]

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[88] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 5.
[89] Utgoff, Victor. "Nuclear Weapons and the Deterrence of Biological and Chemical Warfare." Occasional Paper #36. Henry L. Stimson Center: October 1997, p. 5.
[90] Byrd, Norman R. (Inventor). Chemical Resistant Coatings. United States Patent: 5,858,468. McDonnell Douglas Corporation, St. Louis, MO. p.3.
[91] Alexander, Lexi. "Decontaminating Civilian Facilities: Biological Agents and Toxins." Institute for Defense Analysis, January 1998.

The Air Force must also consider the possibility that other countries may not allow contaminated planes to land in their country.[92] Other countries may also have constraints on disposal methods for decontamination residues or equipment and aircraft that cannot be decontaminated.

8.5 Technological Feasibility

The Air Force must make a policy that the current detection and decontamination technologies are capable of supporting. If the required detection or decontamination capabilities do not exist, then the Air Force must make an interim policy and actively engage in research and development for the needed technologies.

The Air Force must also ensure that all equipment purchased or researched is *necessary* to provide a safe policy, i.e. that the technological capabilities do not exceed the technical requirements.

The Air Force must base its policy on current and expected future technological developments in toxicity data, detection capabilities, and decontamination capabilities.

8.6 Minimization of Costs

The Air Force must consider who will pay for decontaminating CRAF aircraft, the equipment of other services that may have been contaminated while being transported by the Air Force, and Air Force aircraft or equipment that was contaminated due to transporting the equipment of other services.

The Air Force must also consider if the increase in cost of better decontamination methods or detection equipment will increase the safety level, or if a sufficient level of safety can be reached with current systems.

When deciding whether the Air Force should decontaminate in the area of contamination or if the casualties, equipment, or aircraft should return to the US to be decontaminated, if all other factors are equal, the Air Force should choose the least expensive option. Costs should also be compared between carrying out mission operations under restricted conditions and decontaminating the aircraft or using aircraft from somewhere else that have not been subjected to contamination.

The Air Force must also note that if the only decontamination method able to clean to the necessary standard will ruin the aircraft or equipment, it would be a waste of time and resources to decontaminate if there is a cheaper disposal method available.

Costs should be minimized after all other considerations are taken into account.

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[92] Dr. Matthew Meselson, Co-director of the Harvard-Sussex Program on CBW Armament and Arms Limitation. Interview in person. 3/16/00. Dr. Meselson suggested that equipment could be shipped back to the US via the U.S. Navy.
(Author's note: Air Force aircraft, on the other hand, are not currently capable of landing on naval aircraft carriers due to the landing stress incurred. It would also be difficult to load cargo planes onto a carrier by driving them onto it, because the sea-port would have to have docks capable of supporting these large cargo planes.)

9. CONCLUSION AND RECOMMENDATIONS

The current DOD interim chemical standard issued by the Joint Staff, "if you cannot detect it, it is not there,"[93] is not acceptable for the Air Force for two reasons. First, the detectable level of a chemical depends both upon the detection equipment used and the chemical agent in question. Currently, battlefield detectors are not sensitive enough to protect humans not wearing protective gear from harmful effects. The second problem inherent in the DOD interim standard is that the level that is harmful to humans is independent of detection capabilities. If this interim standard is allowed to continue as the standard, problems will arise just as they have arisen with radioactive contamination; the detection technology will advance so far that the detectable levels will be far below harmful levels.

AMC and USTRANSCOM have a prescribed plan for establishing a standard, but this standard will not begin to be formed until the low-level effects study is finalized in FY04. Considering that the current Joint Staff interim standard is not sufficient to protect military personnel or the general population in the event of chemical contamination, the Air Force should consider enacting the following recommendations immediately. The recommendations follow from the issues and information considered in this report only.

9.1 Policy Recommendations

The Air Force should:

⇒ *Apply six criteria (as described earlier in this report) to any decontamination policy*

1. Prevention of health risk to humans
2. Prevention of the spread of contamination to equipment and to returning installations
3. Minimization of mission impact
4. Political feasibility
5. Technological feasibility
6. Minimization of Costs

Each criterion will now be treated in turn by offering a specific recommendation directed at that criterion or by explaining how the suggested decontamination policy addresses that criterion.

[93] David Grube and Lt Col Jimmie Jacobs of AMC. E-mail. 12/3/99.

Criteria 1 & 2: Preventiion of health risks to humans and prevention of the spread of contamination

The decontamination policy for chemically contaminated casualties, aircraft, and equipment must be sufficient to protect humans from harm and prevent the spread of contamination to other equipment, personnel, or airfields.

⇒ *Develop cleanliness standards independent of detection capabilities*

The standard should be set according to the levels necessary to prevent harm to humans and to prevent the spread of contamination. If the available detection or decontamination equipment is not capable of certifying the casualties, equipment, or aircraft to the necessary level, then the Air Force must certify to a more protective level. For example, if the available detector is not sensitive enough certify to the 3X level, then the Air Force must certify the aircraft or equipment to the 1X level and follow the prescribed precautions (outlined in Table 6 below).

⇒ *Follow the Army's guidelines for handling contaminated casualties*[94]

For the details of these guidelines, see Section 7.3.1 titled "Handling Chemically Contaminated Casualties." These guidelines have been accepted throughout DOD and they satisfy the criteria outlined in this report.

⇒ *Develop a decontamination policy with three certification levels for aircraft and equipment*

The Air Force should consider three separate populations for protection: workers/military personnel in full protective gear, workers/military personnel without protective gear, and the general population. These populations should correspond with cleanliness levels similar to the Army's levels for its chemical agents and munitions destruction facilities.

These levels are defined as Levels 1X, 3X, and 5X:[95]

- **Level 1X**: Contaminated objects that have not yet been decontaminated or objects that still contain detectable agent levels at or above the permissible levels for workers/military personnel.[96]

- **Level 3X**: Potentially contaminated objects or previously contaminated objects that have been decontaminated to show concentrations below the permissible levels for workers/military personnel.[97]

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[94] DOD regulation 6055, 9-STD, Army Regulation 385-64 (Ammunition and Explosives Safety Standards), Army Pamphlet 385-61, and Army Training and Doctrine Command (TRADOC) Regulation 385-1 provide guidance for determining the effectiveness of decontamination.

[95] Adapted from the Army's waste contamination levels for its chemical agents and munitions destruction facilities

[96] For Level 1X and Level 3X the level of chemical agent present is to be determined by air monitoring above the material or by approved aircraft detection methods.

[97] Same as footnote 2.

- **Level 5X:** Fully decontaminated objects that show concentrations below the permissible levels for the general population. Level 5X objects must have undergone heat treatment of at least 1000° for at least 15 minutes or a similar process that ensures the destruction of any residual agent that may be inaccessible to chemical treatment in cracks or crevices. Because the permissible hazard concentrations are currently undetermined for percutaneous liquid exposure to the general population, any object showing any concentration of liquid agent cannot be certified at level 5X (until the concentrations are determined).

Table 5, below, defines the permissible levels referred to in the above definitions.

Table 6. Permissible Agent Hazard Concentrations

Agent[98]	Workers/Military Personnel Without Protective Gear		General Population	
	Inhalation Vapor[99] (mg/m^3) (8-hour exposure)	Percutaneous Liquid[100] (ED_{50}, mg for a 70 kg man)** INTERIM STANDARD ONLY	Inhalation Vapor[101] (mg/m^3) (72-hour exposure*)	Percutaneous Liquid
GA	0.0001	880	0.000003	Undetermined
GB	0.0001	1000	0.000003	Undetermined
VX	0.00001	2.5	0.000003	Undetermined
H/HD/HT	0.003	600	0.0001	Undetermined
L	0.003	----	0.003	----

*The sample air must have an agent concentration of less than the specified level for 72 hours.[102]
**Liquid percutaneous dose causing a defined effect in 50% of the exposed animals.

The Air Force should use the Army's permissible chemical agent concentrations used in chemical agents and munitions destruction facilities and the NRC reviewed estimates (detailed above) until the low-level effects study is finalized in FY04. Upon the finalization of this study, the Air Force should compare the results and the target population to those of the existing standard. If the low-level effects study's results surpass the Army's standards in both scientific validity and appropriateness for Air Force applications, then the Air Force should use the new results. The Air Force should seek to determine percutaneous liquid hazard threshold concentrations for military women to replace the interim standards

[98] Toxicity data for other agents that the Air Force is concerned about need to be researched.
[99] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington D.C., 1993. p. 82.
[100] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 1-2. http://books.nap.edu/books/0309057493/html/1.html.
[101] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington D.C., 1993. p. 82.
[102] These values may be more protective than necessary for the Air Force in transporting people (in general, the probability that a person would be on a plane for 72 consecutive hours is extremely low).

in the table above. It should also seek to determine the percutaneous liquid hazard threshold concentrations that will protect the general population.

Next, the Air Force must define the allowable uses for aircraft and equipment certified at each certification level, 1X, 3X, and 5X. Table 6, below, synthesizes the aforementioned criteria with the needs of the Air Force in a recommended decontamination policy. It summarizes the populations that should be allowed to operate, occupy, or use the equipment or aircraft, the risks of spreading contamination to other equipment or airfields, the necessary precautions to prevent this spread, and any special considerations for each certification level.

Table 7. Decontamination Policy: Summary of Details[103]

Level	Population allowed to operate, use, or occupy	Risk of spreading contamination	Precautions needed to prevent spread of contamination	Special considerations
1X	Military personnel/workers in protective gear (Even for personnel in protective gear, exposure should only be allowed if the protective gear's capabilities are known to be sufficient for the given conditions.)	High	• Cover all equipment during loading, transport, and unloading (dispose of the cover material properly at receiving location) • Only transport contaminated material if absolutely necessary (Decontamination before transport is preferable)	• If blood agents are present, even military personnel with protective gear should minimize exposure[104] • If the aircraft's exterior will self-decontaminate in the flight time to the 3X or 5X level, then the aircraft may return without undergoing decontamination first
3X	Military personnel/workers without protective gear	Low[105]	• Cover all equipment during loading, transport, and unloading (dispose of the cover material properly at receiving location) • Test equipment or aircraft (whichever was clean in the beginning) upon arrival to ensure it is still "clean" to the 5X level	• Maintenance workers should wear protective masks and gloves • Any tools used on contaminated equipment or aircraft should be decontaminated to the 5X level after use
5X	General Population	Negligible	• None	• None

*Note: If it is not possible or most cost effective to decontaminate the materials to the necessary level, the Air Force has two options: (1) Control the contaminated materials for a long enough time period that they self decontaminate or (2) Dispose of the materials in a controlled landfill or incinerator that prohibits public access and makes 5X treatment unnecessary.

[103] Adapted by the author for the special needs of the Air Force from the Army's levels for their chemical agents and munitions destruction facilities

[104] Blood agents degrade the capabilities of protective masks. Source: *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper, U.S. Central Intelligence Agency, 1998. p. 26.

[105] The author assumes that any amount of contamination that will spread on take-off or landing will be much lower than the 3X level and will not present a hazard to any of the three populations.

Criterion 3: Minimization of mission impact

The aforementioned decontamination policy allows the Air Force to decide, based upon the individual situation, which level of decontamination is necessary. If the mission requirements can be carried out at Level 3X, then Level 3X is sufficient in that situation. It also allows the Air Force to decide to operate with personnel in protective gear and with equipment covered if the available decontamination method will damage the aircraft or equipment to such an extent that it cannot perform mission essential operations. It is important to note that all CRAF aircraft must be decontaminated to Level 5X to protect the general population. (Currently, this standard has not been accepted by the FAA, so the Air Force will be held liable for any aircraft that become contaminated. This will be discussed further in the political section to follow.)

Criterion 4: Political feasibility

⇒ *Seek regulatory agency approval*

The Air Force should first seek NIOSH and EPA approval of the Air Force decontamination policy. Once the Air Force gains this approval, the Air Force should make an agreement with the FAA concerning the landing of airplanes on commercial or military airstrips and concerning the safe return of CRAF aircraft to commercial service.

The Army has worked together with the NIOSH and the EPA to make its standards acceptable and highly protective. Thus, the Air Force should be able to achieve agreement with them because it will be using the same cleanliness standards.

Once NIOSH and EPA have approved the policy, the FAA will be more likely to approve. Currently, the FAA is willing to work with the Air Force on a policy for landing aircraft in allied countries and in the US. On the other hand, it believes that passengers will not be willing to fly on aircraft that have been through chemical warfare, even if they have been certified as safe for the general population. The Air Force should look to the Japanese handling of the 1995 sarin attack in the Tokyo subway system in looking for ways to appease the legitimate fears of the FAA and the public.

⇒ *Seek individual agreements with allied countries*

Some contaminated aircraft may need to land in allied countries on the way back to the US from a forward-deployed area. The USAF must not wait for international acceptance of the decontamination policy, but must actively seek agreements with critical allied countries (those countries with which cooperation will most likely be needed).

⇒ *Use an adjusted version of AMC and TRANSCOM's schedule for standard/policy implementation*

The Air Force should also make its standard into a DOD-wide standard and then into an international standard. In order to do this, the Air Force should proceed as AMC and USTRANSCOM have prescribed in their timeline and description of efforts (see Introduction), with the following adjustments in the schedule of their timeline:

Table 8. Implementation Timeline

Year	Action/Event
FY01	AMC should have reviewed and amended the established DOD interim standard to be independent of detection technology.
FY03	AMC should have converted the DOD standard into a national standard. The Air Force should be seeking individual agreements with critical allied countries.
FY04	The low-level exposure effects study will be finalized.
FY05	AMC should review and amend the DOD/National standard in light of the low level exposure study
FY08	Projected international acceptance of the amended standard

Criterion 5: Technological feasibility

⇒ *Use laboratory analytical techniques to certify aircraft and equipment for use by the general population*

Currently, battlefield detectors are not sensitive enough to certify aircraft or equipment to the 3X Level. When the Joint Chemical Agent Detector (JCAD) is fielded, it will be able to certify to the 3X Level. Until then, if the Air Force needs to decontaminate equipment or aircraft, it will have to use laboratory analytical techniques. This may currently be impossible to do at a forward-deployed area (outside the scope of this study). If it is impossible, the Air Force should look into providing the necessary laboratory analytical techniques at high-risk bases.

Once the JCAD is fielded, it still will not be able to certify to the 5X Level. Thus, the Air Force will have to use laboratory analytical techniques to certify aircraft and equipment to the 5X Level until battlefield detectors have the capability to do so. Currently, this is a smaller problem than at first it seems. Until the Air Force can convince the FAA that the 5X Level is satisfactory to return CRAF aircraft to commercial service, the need for the 5X Level only applies to transporting military dependents, retirees, civilians, and uncovered equipment. The Air Force can effectively operate a number of aircraft at the 3X Level and still fulfill mission requirements.

⇒ *Continually evaluate the feasibility of alternate decontamination technologies*

For current decontaminants, the Air Force should use CASCAD instead of DS-2 or C-8 because CASCAD's residue is non-toxic and it does not corrode paint, rubber, or aluminum. CASCAD's effects on other aircraft materials should be evaluated. Until those effects are known, aircraft made of sensitive materials will have to be decontaminated with water and aircraft detergent solutions (DS-2 is corrosive to aircraft).

The Air Force should also evaluate the feasibility of low temperature decontamination, CW resistant coatings, Decon Foam 100, and the Atmospheric Pressure Plasma Jet (APPJ) as soon as they are available to improve decontamination capabilities. The Air Force should determine this feasibility by comparing the prospective technology with the current technology in the following areas: non-corrosiveness; level to which the technology can decontaminate; effectiveness in cracks and crevices; toxicity of residues or end products; neutralization of multiple agents; stability in long-term storage; cost; mobility; ease of application; and speed of decontamination.[106]

Criterion 6: Minimization of costs

This decontamination policy allows the Air Force the ability to minimize costs. For example, the Air Force may choose not to decontaminate from the 3X level to the 5X level if the cost to benefit ratio is considered too low. This decision would restrict the uses of the aircraft and/or equipment, but it might not impact mission operations significantly, depending on the specific situation.

The Air Force should carefully consider each decontamination and detection technology that is developed in the future to ensure that the technology is providing a needed improvement at a reasonable cost.

[106] These criteria were modified to apply to aircraft and equipment from the U.S. Army Research Institute Chemical Defense desirable traits of skin decontaminants which can be found at http://206.39.77.2/DMCR/NBC/chemcas/decontam.htm. p.2.

10. ACKNOWLEDGEMENTS

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11. LIST OF ACRONYMS AND ABBREVIATIONS

AC	Hydrogen Cyanide
ACADA	Automatic Chemical Agent Detection Alarm
ACGIH	American Conference of Governmental Industrial Hygienists
AF	Air Force
AF/XONP	Air Force National Security Policy Division
AIHA	American Industrial Hygiene Association
AMC	Air Mobility Command
APPJ	Atmospheric Pressure Plasma Jet
ATSDR	Agency for Toxic Substances and Disease Registry
BW	Biological Warfare
CAM	Chemical Agent Monitor
CASCAD	Canadian Aqueous System for Chemical-Biological Agent Decontamination
CB	Chemical and Biological
CBDP	Chemical and Biological Defense Program
CBW	Chemical and Biological Warfare
CDC	Centers for Disease Control and Prevention
CDEPAT	Chemical Defense Equipment Process Action Team
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CINC	Commander-in-Chief
CK	Cyanogen Chloride
CONUS	Continental United States
CRAF	Civil Reserve Air Fleet
CW	Chemical Warfare
DADS	Direct Application Decontamination System
DATSD (CBD)	Deputy Assistant to the Secretary of Defense for Chemical and Biological Defense
DOD	Department of Defense
DHHS	Department of Health and Human Services
DOE	Department of Energy
DPE	Demilitarization Protective Ensemble
DS2	Decontamination Solution 2
DRR&E	Director, Defense Research and Engineering
DTRA	Defense Threat Reduction Agency
DTS	Defense Transportation System
ECBC	Edgewood Chemical Biological Center
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FM	Field Manual
FY	Fiscal Year
FOA	Swedish Defense Research Establishment
GA	Tabun
GAO	General Accounting Office
GB	Sarin
GD	Soman
ICAM	Improved Chemical Agent Monitor
IDLH	Immediately Dangerous to Life or Health Concentrations (NIOSH)
JCAD	Joint Chemical Agent Detector

JSIG	Joint Service Integration Group
JSLSCAD	Joint Service Light-weight Standoff Chemical Agent Detector
JSMG	Joint Service Military Group
JPO-BD	Joint Program Office for Biological Defense
LIDAR	Light Detection and Ranging
m^3	cubic meter
MAGs	Military Air Guidelines
mg	milligram
MOPP	Mission Oriented Protective Posture
NAS	National Academy of Sciences
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, and Chemical
ng	nanogram
NRC	National Research Council
NTSB	National Transportation Safety Board
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
R&D	Research and Development
RSCAAL	Remote Sensing Chemical Agent Alarm
SBIR	Small Business Innovation Research
TG	Training Guide
TPFDD	Time Phase Force and Deployment Data
US	United States
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAF	United States Air Force
USD (A&T)	Under Secretary of Defense for Acquisition and Technology
USMC	United States Marine Corps
WMD	Weapons of Mass Destruction

12. GLOSSARY OF RELATIVE TERMS[107]

Blister Agent: A chemical agent that can cause blistering of the skin and extreme irritation of the eyes and the lungs. Blister agents are primarily incapacitants, although in large doses, they can cause death. Examples include sulfur mustard, nitrogen mustard, and lewisite.

Blood Agent: A chemical agent that acts on hemoglobin in blood cells and prevents oxigen from reaching the cells. Examples include hydrogen cyanide and cyanogen chloride.

Chemical Warfare: The military use of toxic substances intending the chemical effects on the exposed personnel to result in incapacitation or death.

Choking Agent: A chemical agent that is typically a non-persistent, heavy gas. It irritates the eyes and throat. When inhaled, it can lead to pulmonary edema, which may result in death from lack of oxygen. Examples include chlorine and phosgene.

Cutaneous: Pertaining to the skin.

ECt_{50}: Percutaneous vapor exposure or inhalation vapor exposure causing a defined effect (e.g. incapacitation, severe effects, mild effects, and threshold effects).[108]

ED_{50}: Liquid dose causing a defined effect in 50% of the exposed animals.[109]

G-Series Nerve Agents: Chemical agents of moderate to high toxicity developed in the 1930s that act by inhibiting a key nervous system enzyme. Examples include tabun (GA), sarin (GB), soman (GD), and GF.

ID_{50}: Liquid dose causing incapacitation in 50% of the exposed population.[110]

LCt_{50}: Vapor exposure that produces lethality in 50% of the exposed animals. Ct refers to the product of concentration (C) and exposure time (t). Note that Ct is not necessarily a constant.[111]

LD_{50}: Liquid dose causing lethality in 50% of the exposed animals.[112]

Long-Term Exposure Duration:. "Long-term exposures include continuous exposures or repeated, intermittent exposures that continue daily for more than a 2-week duration."[113]

Milligram: One milligram is one-thousandth of a gram (1 gram = 1000 milligrams)

Nanogram: One nanogram is one-billionth of a gram (1 gram = 10^9 nanograms)

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[107] Except where otherwise noted, the definitions in this glossary were taken from: *The Biological and Chemical Warfare Threat.* Unclassified Staff Paper, U.S. Central Intelligence Agency, 1998.
[108] USACHPPM TG230A.
[109] USACHPPM TG230A.
[110] USACHPPM TG230A.
[111] USACHPPM TG230A.
[112] USACHPPM TG230A.
[113] DOD Strategy. p. 3-4.

One nanogram is one-millionth of a milligram (1 milligram = 10^6 nanograms)

Nerve Agent: A chemical agent that acts by disrupting the normal functioning of the nervous system.

Non-lethal Agents: Chemical agents that can incapacitate but which, by themselves, are not intended to cause death. Examples are tear gas, vomiting agents, and psychochemicals such as BZ and LSD.

Organophosphorus Compound: A compound, containing phosphorus and carbon, whose physiological effects include inhibition of cholinesterase. Many pesticides and almost all nerve agents are organophosphorus compounds.

Percutaneous: Through the skin. When this term is applied to chemical agents it refers to the route of entry into the body.

Persistence: A measure of the duration for which a chemical agent is effective. This property is relative and varies by agent, method of dissemination, and environmental conditions (ex. weather and terrain).

Precursor: A chemical that can be chemically combined with another substance to form a chemical warfare agent. Most precursors controlled through international efforts have commercial uses as well.

Psychochemical Agent: An agent that incapacitates by distorting the perceptions and cognitive processes of the victim.

Pulmonary Edema: The excessive accumulation of fluid in the lung tissue.

Riot Control Agents: Substances, usually having temporary effects, that are used typically by government authorities for law enforcement purposes.

Short-Term Exposure Duration: "In general, this term applies to exposures that exceed the "temporary" duration and continue daily up to a two-week period. This includes continuous exposures and repeated, intermittent exposures."[114]

Temporary Exposure Duration: "An exposure that reflects a brief, one-time or continuous occurrence. Such an occurrence may only last minutes or up to a few hours."[115]

Toxicity: A measure of the harmful effect produced by a given substance on a living organism.

V-Series Nerve Agents: A class of chemical agents developed in the 1950s that act by inhibiting a key nervous system enzyme. They are generally persistent and have a moderate to high toxicity. Examples include VE, VG, VM, VS, and VX.

Vesicant: A blistering agent.

Volatility: A measure of how readily a liquid will vaporize.

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[114] DOD Strategy. p. 3-4.
[115] DOD Strategy. p. 3-4.

13. APPENDICES

13.1 Appendix A: History of Guideline Development for Deployed Military Personnel

13.1.1 APPENDIX A-1 HISTORY

The Mitre Reports, the Stimson Center's toxicity estimates, the CDEPAT estimates and the NRC's review of these estimates, and the Army's short-term and long-term guidelines for deployed military personnel will be discussed in this Appendix.

13.1.1.1 Mitre Reports[116]

In the late 1980's, Mitre was awarded a contract to compile and catalog all current low-level effect data. Mitre did not recommend a methodology for standards development. In fact, the Joint Working Group that commissioned Mitre to do the work seriously debated whether the results were complete or not. Thus, the reports[117] were never used for low-level hazard estimates or standards development.

13.1.1.2 The Stimson Center

The Stimson Center's estimates are focused on the lethal doses. While these doses are important, they do not help the Air Force determine the level at which chemical agents cause adverse effects not as severe as death. The population (age, health, etc.) that they are geared toward is also not explained. These estimates are shown in Appendix A-2.

13.1.1.3 The Army's Chemical Defense Equipment Process Action Team (CDEPAT) Estimates and the National Research Council's (NRC) Review of These Estimates[118]

The Army's Chemical Defense Equipment Process Action Team (CDEPAT) was tasked with reviewing the military's original toxicity data that was developed for offensive purposes. The CDEPAT was to establish exposure limits to protect soldiers. These resulting limits are only for male military personnel and are not adequate for protecting civilians due to the population differences described above. After CDEPAT performed this review, the Department of the Army requested that the National Research Council (NRC) review the CDEPAT report to determine if the estimates were scientifically valid. The NRC reviewed the CDEPAT's estimates for GA, GB, GD, GF, VX, and HD. They did not recommend new toxicity estimates; they only evaluated the CDEPAT's estimates. In 1997, the NRC concluded that even the CDEPAT estimates that were scientifically valid were based on an inadequate toxicity data base (inadequate by current toxicology standards). The NRC recommended that the Army convene an expert panel to develop research for more scientifically sound toxicity values. The specific results of these reviews can be found in Appendix A-2 of this report.

13.1.1.4 Short-term Chemical Exposure Guidelines for Deployed Military Personnel (USACHPPM TG230A)[119]

Short-term toxicity guideline levels have been established for deployed military personnel by the U.S. Army Center for Health Promotion and Preventive Medicine in Training Guide 230A (USACHPPM

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[116] Donna L. Bareis of SAIC. E-mail. 3/14/00.
[117] Classified SECRET
[118] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 1-3. http://books.nap.edu/books/0309057493/html/1.html.
[119] USACHPPM TG230A. Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999. http://chppm-www.apgea.army.mil/imo/ddb/dmd/dmd/TG/TECHGUID/TG230A.PDF

TG230A). The portion of TG 230A pertaining to chemical warfare agents is detailed in Appendix A-3. The Air Force must consider a broader population than deployed military personnel in determining its cleanliness standard. Therefore, these guidelines are of little use for this specific Air Force policy, but may be of use in other areas of concern.

This training guide was developed to assist deployed military personnel in assessing the potential health risks of chemical exposures. The target population consists only of healthy deployed military personnel (men and women). It assumes that personnel will be deployed to a given location or are exposed to a given chemical warfare agent for a temporary period of 1 to 14 days (or less).[120] During this time period, inhalation of airborne contaminants or drinking contaminated water may pose risks. The report established military air guidelines for chemical warfare agents by obtaining data from reviewed military specific literature or from military-sponsored NRC publications.[121]

The USACHPPM obtained the chemical concentration values from reviewed military-specific literature or from military-sponsored NRC publications. Published values from the EPA, AIHA, DOE, ACGIH, and the NIOSH were not available because of the unique military purpose for chemical agents.[122] The military data was originally developed for offensive use, therefore, only values for minimal and severe levels were established. The 14 day MAGs-S for chemical agents were obtained by applying an uncertainty factor (UF) of 10 to the Army/DOD worker 8-hour TWA values.

None of the guidelines were based on the calculated cancer risk from exposure because the cancer-based concentrations were not protective against non-carcinogenic effects. These cancer-based concentrations were determined by a relative cancer risk for the periods of exposure contained in TG230A (threshold concentrations below which carcinogens will not induce cancer are not believed to exist)[123].

If chemical concentrations fall below the one-hour guidelines for minimal effects, temporary exposures would be expected to present negligible risk.[124] Concentrations below the 1-14 day guidelines can be assumed to present minimal, if any, risk for exposure. The air guidelines assume that the exposures are single, continuous events with an averaged exposure concentration over the specified period of time.[125] Note that concentrations of chemicals necessary to produce acute immediate or short-term effects are closer to occupational or emergency exposure guidelines than to ambient environmental air quality criteria or standards meant to protect the general population against chronic health effects from a lifetime of low-level exposure.

The specific guidelines for chemical warfare agents are stated in Appendix A-3.

13.1.1.5 Long-term Exposure Guidelines for Deployed Military Personnel (USACHPPM TG230B)[126]

USACHPPM TG230B (still under development in May 1999) will address the risks associated with long-term exposure to chemical warfare agents. Long-term encompasses periods greater than 14 days, but less than one year.

Once again, the Air Force must consider a broader population than deployed military personnel in determining its cleanliness standard. Therefore, these guidelines will be of use in determining a cleanliness standard for aircraft or equipment that will be used only by active duty military personnel, but they are of little use for determining a standard for aircraft and equipment that will be used by a broader population.

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[120] USACHPPM TG230A. p. 2.
[121] USACHPPM TG230A. p. 16.
[122] USACHPPM TG230A. p. 16-17
[123] USACHPPM TG230A. p.10.
[124] USACHPPM TG230A. p.3.
[125] USACHPPM TG230A. p.7.
[126] USACHPPM TG230A

13.1.2 APPENDIX A-2: CW AGENT TOXICITY ESTIMATES BY CDEPAT, NRC REVIEW, AND STIMSON CENTER

The CDEPAT and NRC reviewed estimates were based on estimates intended for offensive purposes. The estimates that they determined were focused on healthy military males. Therefore, these estimates are not appropriate for the Air Force to use in any situation. See Appendix A-5 for these estimates.

Table 9. CW Agent Toxicity Estimates by CDEPAT, NRC REVIEW, and the Stimson Center

Blister Agents						
Name/Symbol	**Toxicity Type**	**Route and Form of Exposure**	**Existing Military Estimates**	**CDEPAT's Proposed Estimates**	**NRC Subcommittee on Toxic Values Evaluation of CDEPAT's Estimates**	**The Stimson Center's CBW Nonproliferation Project Estimates**
Sulfur Mustard (HD)	LCt_{50}	Percutaneous, vapor	10,000 mg-min/m^3	5,000 mg-min/m^3	Proposed estimate should be lowered	
		Inhalation, vapor	1,500 mg-min/m^3	900 mg-min/m^3	Proposed estimate is scientifically valid	1,500 mg-min/m^3
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	50 mg-min/m^3 (moderate temperature); 25 mg-min/m^3 (hot temperature)	Proposed estimates should serve as interim values	
	Severe effects	Percutaneous, Vapor	2,000 mg-min/m^3 (moderate temp) 1000 mg-min/m^3 (hot temp)	500 mg-min/m^3 (moderate temp) <200 mg-min/m^3 (hot temp)	Proposed estimates are scientifically valid	
		Inhalation, Vapor	200 mg-min/m^3 (moderate temp)	100 mg-min/m^3 (moderate temp)	Proposed estimates are scientifically valid	
	Mild effects	Inhalation, Vapor	>50 mg-min/m^3	25 mg-min/m^3	Proposed estimates are scientifically valid	
	LD_{50}	Percutaneous, Liquid	7000 mg for 70-kg man	1400 mg for 70-kg man	Proposed estimates are scientifically valid	4500 mg agent/kg body weight
	ED_{50}					
	Severe effects	Percutaneous, Liquid	None	610 mg for 70-kg man	Scientifically valid, but should be rounded to 600 mg (lack of precision)	

Lewisite (L)	LCt_{50}	Inhalation, Vapor				1300 mg-min/m^3
	LD_{50}	Percutaneous				**>4500 mg agent/kg body weight**
Nitrogen Mustard (HN-3)	LCt_{50}	Inhalation, Vapor				1500 mg-min/m^3
	LD_{50}	Percutaneous				**4500 mg agent/kg body weight**
Mustard-Lewisite	LCt_{50}	Inhalation, Vapor				1500 mg-min/m^3
	LD_{50}	Percutaneous				**10,000 mg agent/kg body weight**
Phosgene-oxime (CX)	LCt_{50}	Inhalation, Vapor				3200 mg-min/m^3
	LD_{50}	Percutaneous				**25 mg agent/kg body weight**

Nerve Agents						
Name/Symbol	**Toxicity Type**	**Route and Form of Exposure**	**Existing Military Estimates**	**CDEPAT's Proposed Estimates**	**NRC's Subcommittee on Toxic Values Evaluation of CDEPAT's Estimates**	**The Stimson Center's CBW Nonproliferation Project Estimates**
Tabun (GA)	LCt_{50}	Percutaneous, vapor	20,000 mg-min/m^3	15,000 mg-min/m^3	Scientifically valid	
		Inhalation, vapor	135 mg-min/m^3	70 mg-min/m^3	Should be lowered	400 mg-min/m^3
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	2,000mg-min/m^3	Scientifically valid	
	Severe effects	Inhalation, Vapor	None	50 mg-min/m^3	Should be lowered	
	Mild effects	Inhalation, Vapor	0.9 mg-min/m^3	0.5 mg-min/m^3	Should be raised	
	LD_{50}	Percutaneous, Liquid	1500 mg for 70 kg man	1500 mg for 70 kg man	Should be lowered	**1000 mg agent/kg bodyweight**
	ED_{50}	Percutaneous, Liquid	None	880 mg for 70 kg man	Should be lowered	
Sarin (GB)	LCt_{50}	Percutaneous, vapor	15,000 mg-min/m^3	10,000 mg-min/m^3	Scientifically Valid	
		Inhalation, vapor	70 mg-min/m^3	35 mg-min/m^3	Should be lowered	100 mg-min/m^3
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	1200 mg-min/m^3	Scientifically Valid	
	Severe effects	Inhalation, Vapor	35 mg-min/m^3	25 mg-min/m^3	Should be lowered	
	Mild effects	Inhalation, Vapor	2 mg-min/m^3	0.5 mg-min/m^3	Should be raised	
	LD_{50}	Percutaneous, Liquid	1700 mg for 70 kg man	1700 mg for 70 kg man	Estimate should only serve as interim value	**1700 mg agent/kg body weight**
	ED_{50}	Percutaneous,	None	1000 mg for 70	Estimate	

		Liquid		kg man	should only serve as interim value	
Soman (GD)	LCt_{50}	Percutaneous, vapor	None	2500 mg-min/m^3	Scientifically Valid	
		Inhalation, vapor	70 mg-min/m^3	35 mg-min/m^3	Should be lowered	70 mg-min/m^3
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	300 mg-min/m^3	Estimate should only serve as interim value	
	Severe effects	Inhalation, Vapor	35 mg-min/m^3	25 mg-min/m^3	Should be lowered	
	Mild effects	Inhalation, Vapor	None	0.2 mg-min/m^3	Should be raised	
	LD_{50}	Percutaneous, Liquid	350 mg for 70-kg man	350 mg for 70-kg man	Estimate should serve only as interim value	50 mg agent/kg bodyweight
	ED_{50}	Percutaneous, Liquid	None	200 mg for 70-kg man	Estimate should serve only as interim value	
(GF)	LCt_{50}	Percutaneous, vapor	15,000 mg-min/m^3	2,500 mg-min/m^3	Estimate should serve only as interim value	
		Inhalation, vapor	None	35 mg-min/m^3	Should be lowered	
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	300 mg-min/m^3	Estimate should serve only as interim value	
	Severe effects	Inhalation, Vapor	None	25 mg-min/m^3	Should be lowered	
	Mild effects	Inhalation, Vapor	None	0.2 mg-min/m^3	Should be raised	
	LD_{50}	Percutaneous, Liquid	None	350 mg for 70-kg man	Estimate should serve only as interim value	
	ED_{50}	Percutaneous, Liquid	None	200 mg for 70-kg man	Estimate should serve only as interim value	
VX	LCt_{50}	Percutaneous, vapor	None	150 mg-min/m^3	Estimate should serve only as interim value	
		Inhalation, vapor	30 mg-min/m^3	15 mg-min/m^3	Should be lowered	50 mg-min/m^3
	ECt_{50}					
	Threshold effects	Percutaneous, Vapor	None	10 mg-min/m^3	Estimate should serve only as interim value	
	Severe effects	Percutaneous, vapor	None	25 mg-min/m^3	Estimate should serve only as interim	

					value	
		Inhalation, Vapor	25 mg-min/m^3	10 mg-min/m^3	Estimate should serve only as interim value	
	Mild effects	Inhalation, Vapor	0.09 mg-min/m^3	0.09 mg-min/m^3	Scientifically Valid	
	LD_{50}	Percutaneous, Liquid	10 mg for 70-kg man	5 mg for 70-kg man	Should be lowered	10 mg agent/kg bodyweight
	ED_{50}	Percutaneous, Liquid	5 mg for 70-kg man	2.5 mg for 70-kg man	Should be lowered	

**Note*:
LCt_{50}: Vapor exposure that produces lethality in 50% of the exposed animals. Ct refers to the product of concentration (C) and exposure time (t). Note that Ct is not necessarily a constant.
ECt_{50}: Percutaneous vapor exposure or inhalation vapor exposure causing a defined effect (e.g. incapacitation, severe effects, mild effects, and threshold effects).
LD_{50}: Liquid dose causing lethality in 50% of the exposed animals.
ED_{50}: Liquid dose causing a defined effect in 50% of the exposed animals.
ID_{50}: Liquid dose causing incapacitation in 50% of the exposed population.
The lower the number, the more toxic the agent.

Sources:

The existing military estimates, CDEPAT's estimates, and the subcommittee's evaluation were taken from: National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 1-2. **http://books.nap.edu/books/0309057493/html/1.html**.

The Stimson Center's estimates were taken from: Chemical and Biological Weapons Nonproliferation Project. Table 3: Medical Characteristics of Chemical Warfare Agents. p. 1-3. http://www.stimson.org/cwc/cwagnt3.htm. Their estimates were compiled from the Central Intelligence Agency, *The Chemical and Biological Warfare Threat* (Washington, D.C.: Central Intelligence Agency, 1995); Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks, OTA-ISC-559* (Washington, D.C.: Government Printing Office, 1993); Valerie Adams, *Chemical Warfare, Chemical Disarmament* (Indianapolis: Indiana University Press, 1990); Stockholm International Peace Research Institute, *The Problem of Chemical and Biological Warfare Volume I The Rise of CB Weapons* (New York: Humanities Press, 1971); *Chemical Weapons Convention Verification: Handbook on Scheduled Chemicals* (August 1993); Gordon Burck and Charles Floweree, *International Handbook on Chemical Weapons Proliferation* (New York: Greenwood Press, 1991); U.S. Army Center for Health Promotion and Medicine, "Detailed Chemical Fact Sheets," Office to the Deputy for Technical Services, last updated 23 July 1998 [http://chppm-www.apgea.army.mil/dts/dtchemfs.htm]; *Iraqi Weapons of Mass Destruction Programs* (Washington, D.C.: Central Intelligence Agency, February 1998); Edward M. Spiers, *Chemical Warfare* (Urbana: University of Illinois Press, 1986); Robert E. Boyle, *U.S. Chemical Warfare: A Historical Perspective*, (Albuquerque, N.M.: Sandia National Laboratories, August 1998)

13.1.3 APPENDIX A-3: USACHPPM TRAINING GUIDE 230A

13.1.3.1 Comparison with EPA's U.S. General Population Index

USACHPPM TG230A defines minimal, significant, and severe effect levels for military air guidelines concerning chemical warfare agents. These levels correspond to the EPA's U.S. General Population Index Criteria for Particulate Matter in the following manner:

The minimal effect level is comparable to Level 1. The significant and severe effect levels are somewhat more severe than the EPA's Levels 2 and 3. The following table, taken from TG230A, describes the EPA's hazard levels.

Table 10. The EPA's Hazard Levels

U.S. General Population Index Criteria for Particulate Matter (PM_{10})			
Level (Ascending Hazard Level)	Concentration (ug/m^3)	General Civilian Population Health Effects Statements	General Civilian Population Health Effects Statements
1	255-354	Increased respiratory symptoms (e.g. coughing) and aggravation of lung disease (e.g. asthma)	Elderly, children, and people with lung disease (e.g. asthma) should restrict heavy exertion; others should minimize prolonged exertion
2	355-424	Significant increase in respiratory symptoms (e.g. coughing, mucous) and aggravation of lung disease (e.g. asthma)	Elderly, children, and people with lung disease (e.g. asthma) should avoid outdoors; others should minimize moderate to heavy exertion
3	425-604	Serious risk of respiratory symptoms (e.g. coughing, mucous, shortness of breath) and aggravation of lung disease (e.g. asthma)	All should minimize outdoor exertion

13.1.3.2 USACHPPM TG230A Chemical Exposure Guidelines and Discussion

Table 11. USACHPPM TG230A Short-Term Chemical Exposure Guidelines for Deployed Military Personnel

Compound	1-Hour MAGs-S ppm (mg/m^3)*			1-14 Day MAGs-S ppm (mg/m^3)	Notes
	Minimal effects level	Significant effects level	Severe effects level		
GA (Tabun)	0.01*	ND	0.1*	0.00001*	Values based on anti-chlolinesterase activity; miosis for 1-hour values. 1-hr – Ct; 1-14 day = TWA (8 hr)/10
GB (Sarin)	0.008*	ND	0.1*	0.00001*	Values based on anti-chlolinesterase activity; miosis for 1-hour values. 1-hr – Ct; 1-14 day = TWA (8 hr)/10
GD (Soman)	0.003*	NA	0.05*	0.000003*	Values based on anti-chlolinesterase activity; miosis for 1-hour values. 1-hr – Ct; 1-14 day = TWA (8 hr)/10
Hydrogen Cyanide	4.7 (5.2)	10 (11)	25 (27)	0.05^S (0.05)	Dermal exposures may contribute to total dose; sweetish, almond-like odor; concentrations of 45-54

					ppm may be tolerable for 0.5-1.0 hr; 110-135 ppm may be fatal after 0.5-1.0 hr or later
Lewisite	0.003[C]	ND	ND	0.003[C]*	
Phosgene	0.1 (0.4)	0.2 (0.81)	1 (4)	0.01 (0.04)	Lethality may occur at lower (5 ppm) concentrations due to pulmonary edema.
Sulfur Mustard (HD)	0.42*	ND	1.7	0.003[C]*	Carcinogen. 1-14 day = TWA (8 hr).
VX	0.0015*	NA	0.02*	0.00003*	Values based on antichloinesterase activity. 1-hr = Ct; 1-14 day = General Population Limit.

Notes:
MAGs-S = Military Air Guidelines – Short Term
C = Ceiling value (ACGIH, 1998) The effects depends less on the length of time individuals are exposed to it and more on the chemical concentration. Thus, the ceiling value should not be exceeded for any duration at the threshold effect level[127].
S = Skin notation; dermal exposures have the potential for significant contribution to overall dose.
TWA (8hr)/10 = The 14 day MAGs-S for chemical agents were obtained by applying an uncertainty factor (UF) of 10 to the Army/DOD worker 8-hour TWA values.

Source: USACHPPM TG230A Appendix C (C-11, 12, 13, 14, 17, 18, 20)

In May of 1999, the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) produced Training Guide (TG) 230A to be used as a tool for short-term chemical exposure guidelines for deployed military personnel. It is designed to address the potential adverse health impacts among healthy deployed military personnel (male and female). The exposure levels are not mandated exposure limits; they are criteria that should be used to identify potential risks necessitating consideration in deployment mission decision making and risk management.[128] These levels are "estimates of the thresholds above which there would be an unacceptable likelihood of observing the defined effects," taking into account that hypersensitive individuals exist in all populations who may experience adverse responses below the exposure concentrations at which most individuals would respond[129]. It is important to note that "doses protective against unacceptable carcinogenic, reproductive, and fetal developmental risks have not been clearly defined in all cases."[130]

The USACHPPM obtained the chemical concentration values from reviewed military-specific literature or from military-sponsored NRC publications. Published values from the EPA, AIHA, DOE, ACGIH, and the NIOSH were not available because of the unique military purpose for chemical agents.[131] The military data was originally developed for offensive use, therefore, only values for minimal and severe levels were established.

The 1-14 day MAGs-S for chemical agents were obtained by applying an uncertainty factor (UF) of 10 to the Army/DOD worker 8-hour TWA values. Out of the TG230A guidelines, these 1-14 day MAGs-S represent the closest approximation to the environment that everyday unprotected military personnel would experience. (A pilot and crew's exposure time would be more than one hour for the majority of flights). Everyday personnel would be exposed for more than 14 days overall, but this exposure may not be continuous, as it might be with deployed personnel. (For example: everyday pilots may fly three times a week for a month, then they may not fly the next month, and may continue flying the month after).

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[127] USACHPPM TG230A. Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999. http://chppm-www.apgea.army.mil/imo/ddb/dmd/dmd/TG/TECHGUID/TG230A.PDF p. 16.
[128] USACHPPM TG230A: Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999 Version. p. 1-2.
[129] USACHPPM TG230A: Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999 Version. Acknowledgements page.
[130] USACHPPM TG230A: Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999 Version. Acknowledgements page.
[131] USACHPPM TG230A. p. 16-17

13.2 Appendix B: Toxicity Level Research Focus and Specific Research Programs Topic Description

13.2.1 APPENDIX B-1: RESEARCH FOCUS

The ongoing research on chemical toxicity levels seeks to establish scientific criteria that define the lowest levels personnel may be exposed to without measurable biomedical effects. A numerical limit for "low-level" is not defined, but a range will be assumed, the upper boundary of which will be levels "not sufficient to endanger health immediately."[132]

The Subcommittee on Toxicity Values for Selected Nerve and Vesicant Agents recommended that the Army convene an expert panel that would develop a research strategy for developing more scientifically sound toxicity values for chemical agents. If techniques such as structure-activity relationships, uncertainty factors, and in vitro systems do not appear useful for estimating human-toxicity values, the subcommittee may recommend animal and human experimentation. This research is needed because the current data on chemical agents were only available for a few harmful health effects, including death, incapacitation, cholinesterase inhibition, rhimorrhea, meiosis, erythema, and vesication. The subcommittee's evaluations of CDEPAT's estimates were based on this limited toxicity database.[133]

The Subcommittee also recommended that experimental designs should include:

- "Define if and when experiments with humans are appropriate.
- In the absence of human experimentation, define the most appropriate animal model for each specific toxicity value and agent, including the end points to be observed.
- Define the adequacy of the design in determining the toxicity values for healthy female as well as healthy male military personnel.
- Define the requirements for observation of reversibility of adverse health effects.
- Identify adverse health effects at the low end of the dose-response curve to determine threshold exposure levels.
- Identify confidence limits for the proposed estimates as a measure of the uncertainty of the estimated incidence of toxic effects.
- Identify potentiation or antagonistic effects from exposures to mixtures of chemical agents.
- Identify more sensitive biological markers of exposure and effects for CW agents[134]."

The DOD Strategy to Address Low-Level CW Agent Exposures identifies that research is needed on the effects of CWAs at higher and lower concentrations and long-term exposure durations. It also recommends a follow-on study to the National Academy of Sciences (NAS) study on effects of human CWA exposure: Possible Long-Term Effects of Short-Term Exposure to Chemical Agents; NAS, 1984.[135]

The goal of this overall strategy is to "provide for protection and detection and surveillance capabilities for low-level exposures that are appropriate for the general military population (i.e. healthy adults of 18-55 years of age) for a variety of deployment scenarios."[136] Due to the use of the Civil Reserve Air Fleet in war-time, the Air Force must also be concerned with the decontamination of civilian aircraft and effects of low-level exposures on civilians, not just military personnel. Currently, no DOD Strategy exists to address these research needs.

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[132] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 5.
[133] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 3. http://books.nap.edu/books/0309057493/html/1.html.
[134] National Academy Press. Review of Acute Human-Toxicity Estimates for Selected Chemical-Warfare Agents (1997). p. 16. http://books.nap.edu/books/0309057493/html/1.html.
[135] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 29.
[136] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 8.

Appendix B-2: Current Research Programs[137]

In the area of identifying a threat or hazard several projects are being done. Work is currently being done by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) as a draft response to the GAO report claiming that DOD does not have a strategy to address low-level chemical agents. Field Manual 100-14 (Risk Management, 23 April 1998, U.S. army Training and Doctrine Command) describes a 4-step process of risk management process for deployment decision-making. This includes the first step of hazard identification, including a process for assessing the severity and the probability of a hazard. The Defense Intelligence Report DI-1816-8-99 Jan 99 on the Medical Intelligence Assessment of Deployment Environmental Health Risks was produced by the Epidemiology and Environmental Health Division. It establishes a process to evaluate and determine environmental health risks that may influence operational success. The assessment categorizes risks as acute (Tier I and II) and long-term (Tier III).

The CHPPM is doing work on definitions and proposed strategy for low level exposure, long-term exposure, short-term exposure, and temporary exposure.

The IOM Study Panel/USAMRICD is also doing work in each of these areas. For research on low level exposure, it has contracted a research panel to review the standard definitions for low level CWA's in man and appropriate model species. For long-term exposure, short-term exposure, and temporary exposure, it has contracted research panels to review and set the standard definitions for the purposes of chronic studies, subchronic studies, and acute studies, respectively. Each of these studies includes duration and dose scheduling.

The ECBC (JSIG), CHPPM, USAMRICD, and Herman vanHelden at TNO Prins Maurits Lab (Netherlands/MRMC) are doing research on single event single agent exposures. Repeated, chronic, and long-term exposures are being researched by the CHPPM0SECWG, UMAB/USAMRICD, Texas Tech University Health Science Center (USAMRICD), WRAIR/USAMRICD, USAMRICD, and Lovelace Respiratory Research Institute, Albuquerque (NM/MRMC).

The TG231 of the CHPPM describes field occupational hazards from chemicals. Battlefield hazards and operational risk management from chemicals are addressed by FM 100-14, AFI 91-213, AFPAm 91-215, and OPNAV Instruction 3500. Battlefield chemical hazards are being studied by the CHPPM-HHA and the USAMRMC. The MRMC's studies are being carried out by the following institutes and people: Medical Follow-up Agency Institute of Medicine, National Academy of Sciences; Barry W. Wilson of University of California, Davis; M. Abou-Donia, Ph.D. of Duke University Medical Center; Satu M. Somani, Ph.D. of Southern Illinois University; and Carl Olson, Ph.D. of Battelle.

[137] DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999. p. 21-23.

13.3 Appendix C: Low-Level Definition by DOD Strategy to Address Low-Level CW Agent Exposures

"Low-Level Exposure Concentration: For a given chemical, low-level exposure concentrations include exposure for a given duration below which no significant adverse health effects (immediate or delayed) are presumed to occur in accordance with the best available scientific data.[138]

Duration of Exposure: The period of time military personnel may be exposed to chemical warfare agents or other hazards cannot be precisely estimated. However, the following duration periods describe generalized durations of exposures that deployed forces may encounter. This grouping provides a systematic means of focusing research. For example, primary focus will first be to identify low-level concentrations and associated effect for temporary exposures, as this is the most probable exposure duration anticipated for deployed forces. Short-term exposure durations may also be anticipated and, therefore, would be considered within the research strategy. Long-term exposures to chemical agents, however, are relatively unlikely to occur and would therefore be of lower priority when considering research needs. This is supported by existing doctrine in which the time period of interest used by NBC planners is generally between 6 and 48 hours."[139]

"*Temporary Exposure Duration:* an exposure that reflects a brief, one-time or continuous occurrence. Such an occurrence may only last minutes or up to a few hours.

Short-Term Exposure Duration: In general, this term applies to exposures that exceed the "temporary" duration and continue daily up to a two-week period. This includes continuous exposures and repeated, intermittent exposures.

Long-Term Exposure Duration. Long-term exposures include continuous exposures or repeated, intermittent exposures that continue daily for more than a 2-week duration."

[138] While the effects are dependent on the concentration and the duration of exposure, the relationship between concentration and the time (duration) is not linear (i.e. data for a concentration X and a duration Y yielding an effect Z should not be extrapolated linearly.)

[139] DOD Strategy. p. 3-4.

13.4 Appendix D: Lethal Human Doses for CW Agents

LETHAL HUMAN DOSES[140]

	Intravenous (LD_{50}, mg/kg bodyweight)	Inhalation (LCt_{50},mg-min/m^3)
GA	0.014	135-400
GB	0.014	70-100
VX	0.008	20-50
H/HD/HT	--	10,000
L	--	100,000

*Note: LCt_{50} (vapor) and LD_{50} (liquid) represent dosage that result in 50 percent lethality in the exposed population.

[140] National Research Council. Alternative Technologies for the Destruction of Chemical Agents and Munitions. National Academy Press: Washington, D.C. 1993. p. 82.

13.5 Appendix E: Regulatory Agency Review

13.5.1 ACGIH (AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS)

The ACGIH is not a government agency. It is a professional society devoted to technical and administrative aspects of environmental and occupational health. It develops Threshold Limit Values that serve as guidelines for use in the practice of workplace industrial hygiene. These concentration limits are set at levels expected to be without adverse effects during repeated daily exposure for almost all workers. The TLVs are TWA concentrations not to be exceeded during any 8-hour work-shift of a 40-hour week.[141]

The ACGIH has set a ceiling value on Lewisite, but it does not have published values for the rest of the chemical warfare agents due to their unique military purpose.[142]

13.5.2 AIHA (AMERICAN INDUSTRIAL HYGIENE ASSOCIATION)

13.5.3 ATSDR (AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires the ATSDR and the EPA to jointly develop a list of the most common hazardous substances along with a toxicological profile for each substance. In response to this requirement, the ATSDR developed Minimal Risk Levels (MRL), which are estimates of the daily human exposures to a hazardous substance that can be tolerated without appreciable risk of adverse non-cancer health effects over the specified exposure duration. These levels are usually based on the "most sensitive substance-induced end point considered to be of relevance to humans."[143] **Acts of war, though, are a legal defense to CERCLA.**[144]

13.5.4 CDC (CENTERS FOR DISEASE CONTROL AND PREVENTION)

The Centers for Disease Control and Prevention (CDC) exists under the Department of Health and Human Services. It performs many of the administrative functions for its sister agency, the Agency for Toxic Substances and Disease Registry (ATSDR). The Director of CDC also serves as the Administrator of ATSDR.

The CDC's mission is "to promote health and quality of life by preventing and controlling disease, injury, and disability.[145]

In 1988, the CDC established general population levels for sarin and cyclosarin. The general population level represents the highest level of the chemical at which "long term exposure to these concentrations would not create any adverse effects."[146]

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[141] Spektor, Dalia M. RAND. A Review of the Scientific Literature as it Pertains to the Gulf War Illnesses. Volume 6: Oil Well Fires. Chapter 2. Environmental Standards. U.S. Standards and Recommendations. http://www.gulflink.osd.mil/library/rowl/mr1018ch2.html. 12/4/99

[142] USACHPPM TG230A. Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. May 1999. http://chppm-www.apgea.army.mil/imo/ddb/dmd/dmd/TG/TECHGUID/TG230A.PDF p. 16, C-15.

[143] Spektor, Dalia M. RAND. A Review of the Scientific Literature as it Pertains to the Gulf War Illnesses. Volume 6: Oil Well Fires. Chapter 2. Environmental Standards. U.S. Standards and Recommendations. http://www.gulflink.osd.mil/library/rowl/mr1018ch2.html. 12/4/99

[144] Olexa, M.T. and Rebecca L. Trudeau. "NASD: The Comprehensive Environmental Response, Compensation, and Liability Act." University of Florida. http://www.cdc.gov/niosh/nasd/docs2/as68400.html. p. 3. 2/28/00

[145] CDC. About CDC. http://www.cdc.gov/aboutcdc.htm. 3/11/00.

[146] Army IG Report into Demolition of IRAQ Ammunition. http://www.gulflink.osd.mil/cgi-bin/texis/search/gulfsearch/~MjvezzsqoeGzEGkEq.../view.htm. 12/4/99.

13.5.5 DHHS (DEPARTMENT OF HEALTH AND HUMAN SERVICES)

The Department of Health and Human Services is "the United States government's principal agency for protecting the health of all Americans and providing essential human services, especially for those who are least able to help themselves."[147] The eight federal public health agencies within the DHHS include CDC and ATSDR, which are concerned about toxic chemical levels.[148]

13.5.6 EPA (ENVIRONMENTAL PROTECTION AGENCY)

The EPA sets its standards to protect the general population from increased health risks due to exposures to ambient pollutants. These standards include a margin of safety that makes them much lower than occupational standards. They are meant to protect the most vulnerable people, such as small children, people with respiratory and other diseases, and the elderly.[149]

The EPA has a Standard Hazmat Response Model that it will follow in the case of a bioterroist attack.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), passed in 1980, gives the EPA the right to "investigate and clean up abandoned sites contaminated by hazardous substances and provides a trust fund for that purpose."[150] It designates liability for site pollution and forces parties to pay, at least in part, for the cleanup costs. **Acts of war, though, are a legal defense to CERCLA.**

13.5.7 FAA (FEDERAL AVIATION ADMINISTRATION)[151]

The Federal Aviation Administration focuses on three mission goals: safety, security, and system efficiency. It strives to reduce the occupant risk meaning reducing the risk of mortality to a passenger or flight crew member on a typical flight.[152]

The FAA flight safety standards prevent, as much as possible, the use of CRAF in potential CBW environments (demonstrated in Desert Storm and in Somalia). Should an aircraft become contaminated, the FAA would like to use a DOD airfield to prevent the contamination of and liability for shutting down a commercial airfield.

If the commercial insurance market refuses to insure the aircraft (highly likely with the threat of a CBW environment), the FAA provides war risk insurance to the CRAF suppliers. If a CRAF aircraft is contaminated with a persistent chemical agent that will not submit to the normal decontamination methods of aging or cold soaking at altitude, the FAA has indicated that DOD will be required by law to reimburse the FAA for any pay out of the insurance fund for this CRAF loss. The FAA also believes that the mechanics will be unwilling to work on an aircraft due to the fear of drilling into or coming into contact with a contaminated area that the decontamination method missed.

On the issue of decontaminating an aircraft's interior, the FAA believes that even if decontamination is possible and performed, passengers will not be willing to fly on the aircraft.

Due to the aforementioned concerns, the FAA does not feel that it will use a decontamination policy of standards for CRAF aircraft resuming civilian operations if the Air Force makes one. The FAA

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[147] DHHS. HHS: What we do. http://www.hhs.gov/about/profile.html. 3/11/00.
[148] CDC. About CDC. http://www.cdc.gov/aboutcdc.htm. 3/11/00.
[149] Spektor, Dalia M. RAND. A Review of the Scientific Literature as it Pertains to the Gulf War Illnesses. Volume 6: Oil Well Fires. Chapter 2. Environmental Standards. U.S. Standards and Recommendations. http://www.gulflink.osd.mil/library/rowl/mr1018ch2.html. p.4. 12/4/99
[150] Olexa, M.T. and Rebecca L. Trudeau. "NASD: The Comprehensive Environmental Response, Compensation, and Liability Act." University of Florida. http://www.cdc.gov/niosh/nasd/docs2/as68400.html. p. 1. 2/28/00
[151] Except where otherwise noted, all information in this section was provided by Dwight Moore, USTC JA. E-mail. 3/9/00.
[152] FAA. Safety, Security, and System Efficiency. http://www.faa.gov/safety2.htm. 3/11/2000.

will consider any CRAF aircraft that become contaminated as a loss. This stance is held by both the FAA insurance personnel and FAA flight standards personnel who both possess equal input on CRAF issues.[153]

On the other hand, the FAA sees the need for a cleanliness standard for allowing contaminated or decontaminated aircraft to land on commercial airfields. It may be willing to accept such a standard after it has been researched and established by the USAF.

The FAA also has established rules for operating in a foreign country in FARS Part 121, "Operational Requirements: Domestic, Flag, and Supplement Operations" Sec 121.11: "Rules applicable to operations in a foreign country." "Each certificate holder shall, while operating an airplane within a foreign country, comply with the air traffic rules of the country concerned and the local airport rules, except where any rule of this part is more restrictive and may be followed without violating the rules of that country."

13.5.8 NIOSH (NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH)

The Occupational Safety and Health Act of 1970 created the National Institute for Occupational Safety and Health (NIOSH) as part of the Centers for Disease Control (CDC). NIOSH periodically revises and develops recommended exposure limits for hazardous substances. It evaluates all relevant and available biological, medical, and other information. Its recommendations are then sent to the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration for use in declaring legal standards. "NIOSH's time waited average concentrations (TWA's) are the maximum recommended exposures in the workplace for up to a 10-hour workday during a 40-hour work week."[154] Also, during any 8-hour work shift of a 40-hour work week, these concentrations must not be exceeded.

13.5.9 NATSB (NATIONAL TRANSPORTATION SAFETY BOARD)

The National Transportation Safety Board is "an independent Federal agency that investigates every civil aviation accident in the United States and significant accidents in the other modes of transportation, conducts special investigations and safety studies, and issues safety recommendations to prevent future accidents."[155] The NATSB interests in an Air Force decontamination policy would most likely be focused on ensuring that the decontamination methods employed did not make the aircraft structurally, mechanically, or electronically, unsafe to fly. If a commercial aircraft or a formerly military aircraft converted to civilian that had been through chemical warfare or had been decontaminated was involved in an accident the NATSB would be involved in investigating the accident. The possibility of a commercial aircraft going through chemical warfare is significantly smaller than that of a military aircraft, due to the precautions taken by the military to keep CRAF uninvolved in a CBW environment.[156]

13.5.10 OSHA (OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION)

The Occupational Safety and Health Administration exists under the Department of Labor. It establishes and enforces protective standards for the health of American workers.[157] OSHA currently does not have publicly established hazardous levels for chemical warfare agents.

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[153] Dwight Moore, USTC JA. E-mail. 3/9/00.

[154] Spektor, Dalia M. RAND. A Review of the Scientific Literature as it Pertains to the Gulf War Illnesses. Volume 6: Oil Well Fires. Chapter 2. Environmental Standards. U.S. Standards and Recommendations. http://www.gulflink.osd.mil/library/rowl/mr1018ch2.html. p.3. 12/4/99.

[155] NATSB. About NATSB. http://www.ntsb.gov/Abt_NTSB/guide.htm. 3/11/00.

[156] William Heisel, USTRANSCOM J5-SR. E-mail. 2/28/00.

[157] OSHA. OSHA's Mission. http://www.osha.gov/oshinfo/mission.html. 3/11/00.

13.5.11 REGULATORY AGENCIES OF OTHER COUNTRIES

The specific regulatory agencies of other countries are not outlined in this report. In determining the applicable regulations in other specific countries, the US could look to the declarations made under the Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction. This convention requires the participating countries to provide the following information about their facilities that may be of use:[158]

- "A detailed description of the safety and medical measures in force at the facility
- "The quality assurance and control manuals and the environmental permits that have been obtained.
- "The national standards for safety and emissions that the destruction facilities must satisfy."

13.5.12 INTERNATIONAL LAW

International law will hold the country that used the CBW agents accountable for violations. There are also international laws concerning the destruction of chemical weapons. The governing laws include: Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and of Bacteriological Methods of Warfare, 17 June 1925; Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, 10 April 1972; Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques, 10 December 1976; Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction, 13 January 1993.[159] The Chemical Weapons Convention and Biological Weapons Conventions also govern the use and destruction of chemical and biological weapons.

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[158] Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and On Their Destruction. Annex on Implementation and Verification. Part IV (A) Destruction of CW and Its Verification Pursuant to Article IV. 31. http://www.unog.ch/frames/disarm/distreat/chemical.htm 3/11/00.

[159] Major International Instruments on Disarmament and Related Issues. http://www.unog.ch/frames/disarm/distreat/warfare.htm. 3/11/00.

13.6 Appendix F: Detection Technologies

13.6.1 APPENDIX F-1: CURRENT DETECTOR DESCRIPTIONS[160]

M8 Chemical Detection Paper detects and identifies liquid chemical agents in 30 seconds with manual identification.

M9 Chemical Detection Paper detects liquid chemical agents, but does not identify the agents. It can detect nerve or blister agent droplets down to a diameter of 100 microns. It must be noted that antifreeze, liquid insecticides, or petroleum products may cause false positives. This detection paper is used on the outside of Battle Dress Overgarments.

The M8A1 Automatic Chemical Agent Alarm samples the air for nerve agent vapors. It is the only remote continuous air sampling alarm that the U.S. Army operates.

The M21 Remote Sensing Chemical Agent Alarm (RSCAAL) can detect clouds of blister and nerve agents up to 5 km away. It is a stand-alone system mounted on a tri-pod.

The Automatic Chemical Agent Detector/Alarm (ACADA) will replace the M8A1. It detects all known nerve and blister agents in a stand-alone configuration. It is operated by a joint U.S. Air Force and U.S. Army project.

The Chemical Agent Monitor (CAM) and Improved CAM (ICAM) can detect nerve and blister agent vapors. The CAM can display a very high vapor hazard presence (7-8 bars), a high vapor hazard presence (4 to 6 bars), and a low vapor hazard presence (1-3 bars).[161]

The M256A1 Chemical Agent Detection Kit both detects and identifies liquid and vapor chemical agents. It can detect very low concentrations of chemical vapors.

Additionally, the M272 Water Testing Kit tests water contaminated by nerve and blister agents, cyanide, and lewisite.

13.6.2 APPENDIX F-2: CHEMICAL DETECTION RESEARCH PROJECTS

USAMRICD, TNO Prins Maritus Lab, ECBC, and JSMG are exploring biomarkers for CWA exposure. The USAMRICD is researching the use of differential display PCR to determine altered gene expression in cultured human keratinocytes after exposure to HD; and improved detection methods for nerve agent and HD exposures from biological samples. TNO Prins Maritus Lab is conducting research concerning improved detection methods for HD metabolites from biological samples. The ECBC is exploring biomarkers for CWA exposure-differential display PCR for determining OP altered gene expression. The JSMG and ECBC are jointly looking into invitro biomarkers of threat agents[162].

The military is also exploring detection suites such as the Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD) and the U.S. Joint Service Chemical Miniature Agent Detector (JSCMAD). The JSLSCAD will allow for on the move 360° coverage and will provide standoff detection between 3-8 km. The MSCMAD will be small enough to fit in the front pocket of the battle dress overgarment, will be able to operate for 72 hours, will weigh less than 1 kg, and will draw a maximum of

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[160] Chem-Bio Reference. Chemical and Biological Detection, Analysis, Decontamination and Medical Response. http://chembio.janes.com/subscribe/reference/07detection.html. p. 8-10.

[161] The DOD Strategy to Address Low-Level Exposures to Chemical Warfare Agents, May 1999, on page 16 defines these levels differently: A Chemical Agent Monitor (CAM) reading between 0 and 1 bars is, in general, an acceptable level of contamination. When the reading lies between 1 and 4, there is moderate contamination (one gram of agent per square meter, as defined by Army's Field Manual (FM) 3-3). Heavy contamination (defined by the FM 3-3 as ten or more grams of agent per square meter) exists when the reading is between 5 and 8 bars on the CAM.

[162] DOD Strategy to Address Low-Level CWA Exposures, May 1999. p.24.

2 watts of power. It will be able to detect nerve, blister, and choking agents at levels below the incapacitating level.[163]

[163] Chem-Bio Reference. Chemical and Biological Detection, Analysis, Decontamination and Medical Response. http://chembio.janes.com/subscribe/reference/07detection.html. p. 10.

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